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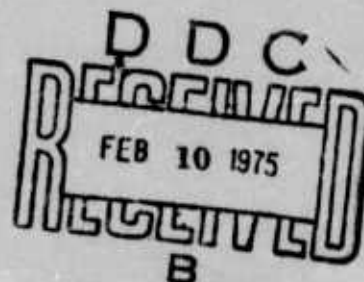
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AFML-TR-74-106

AD B002048

**ABSTRACTS OF AF MATERIALS
LABORATORY REPORTS
JANUARY 1973 - DECEMBER 1973**

TECHNICAL REPORT AFML-TR-74-106



JULY 1974

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**AIR FORCE MATERIALS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433**

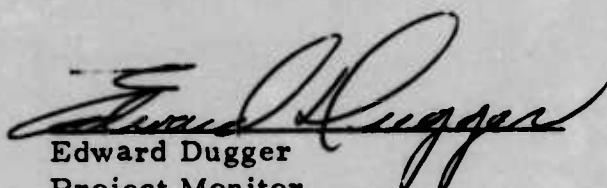
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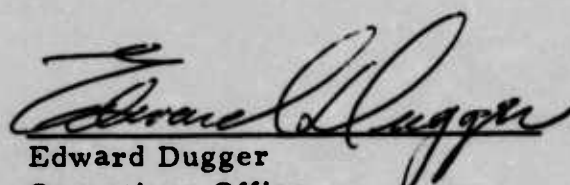
This report was prepared by the Scientific and Technical Information Office (STINFO), Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio, under job order number 73810328. Mr. Edward Dugger (AFML/DO) was the project monitor.

This technical report has been reviewed and is approved for publication.



Edward Dugger
Project Monitor

FOR THE COMMANDER



Edward Dugger
Operations Office

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4. TITLE (and Subtitle) Abstracts of AF Materials Laboratory Reports January 1973 - December 1973		5. TYPE OF REPORT & PERIOD COVERED Final Technical Report	
		6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s) Job Order 73810328	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Materials Laboratory (AFML/DO) Wright-Patterson Air Force Base, Ohio		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Materials Laboratory (AFML/DO) Wright-Patterson Air Force Base, Ohio		12. REPORT DATE July 1974	
		13. NUMBER OF PAGES 253	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED	
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) OFFICIAL USE ONLY			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Abstracts Materials Information Air Force Materials Laboratory Reports Materials Research Bibliography			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Technical reports published by the Air Force Materials Laboratory during the period 1 January 1973 - 31 December 1973 are abstracted herein. They are presented in groups corresponding to the divisions of the Laboratory. In addition to the abstract text, the report number, investigator, AFML project monitor, contractor, contract number,			

AFML project/task number, report date, and AMIC accession numbers are given. Reports on research conducted by the Air Force Materials Laboratory personnel as well as that conducted on contract are included.

A number of indices are included in the report: subject (KWOC), AD accession number, AFML report number, contract number, contractor, investigator and AFML project monitor.

FOREWORD

Technical reports published by the Air Force Materials Laboratory during the period 1 January 1973 - 31 December 1973 are abstracted herein. Reports on research conducted by Air Force Materials Laboratory personnel as well as that conducted on contract are included. The abstracts are separated into sections corresponding to the divisions of the laboratory with seven indices provided. The accession number cited with each abstract provides access to the document itself in the Air Force Materials Laboratory's document collection.

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ABSTRACTS OF TECHNICAL REPORTS

OPERATIONS OFFICE (AFML/DO)

REPORT NO: AFML-TR-73-5 AD 758 805
ACCESS NO: 201,537 January 1973
TITLE: ANALYTICAL CHEMICAL RESEARCH,
SUPPORT AND SERVICE
AUTHOR(S): J. E. Katon
CONTRACT NO: F33615-72-C-1040
CONTRACTOR: Miami University
PROJECT MONITOR: F. F. Bentley (AFML/DO)
PROJECT NO: 7360
TASK NO: 736005
ABSTRACT: This report summarizes the research and support programs covering determination of molecular structures, characterization of materials and development and application of analytical techniques of various kinds. Major areas of research were in emission spectrometry, mass spectrometry, microchemical analyses and vibrational spectroscopy. In emission spectrometry special techniques for the analysis of strontium, calcium and cadmium fluorides were developed. Vibrational spectroscopic studies concentrated on far infrared group frequencies, the structures of acids, and crystallization phenomena. Mass spectrometric studies involved the design, installation and evaluation of a chemical ionization source for a standard analytical mass spectrometer as well as development of an analytical method for trace amounts of water.

REPORT NO: AFML-TR-73-53 AD 761 808
ACCESS NO: 201,462 April 1973
TITLE: THE USE OF SELECTED PORTIONS OF
TECHNICAL DOCUMENTS AS SOURCES OF
INDEX TERMS AND EFFECT ON INPUT COSTS
AND RETRIEVAL EFFECTIVENESS
AUTHOR(S): H. H. Schumacher; J. F. March; F. L. Scheffler
CONTRACT NO: F33615-71-C-1069
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: E. Dugger (AFML/DO)
PROJECT NO: 7381
TASK NO: 738103
ABSTRACT: A correlation between recall and quantity of text which served as a source of index terms on input can reasonably be expected. Specifically, recall should decrease as the quantity of text serving as a source of index terms is restricted. On the other hand, the time for indexing and therefore the input cost should be less, thus

ABSTRACT (Cont'd): establishing a tradeoff between input cost and retrieval effectiveness. It was desired to quantify the effect of restricting the source text on both retrieval effectiveness and input cost.

REPORT NO: AFML-TR-73-143 AD 770 570
 ACCESS NO: R-67 September 1973
 TITLE: ABSTRACTS OF AF MATERIALS LABORATORY
 REPORTS JANUARY 1972 - DECEMBER 1972

CONTRACTOR: Internal

PROJECT MONITOR: E. Dugger (AFML/DO)

ABSTRACT: Technical reports published by the AFML during the period 1 January 1972 - 31 December 1972 are abstracted herein. They are presented in groups corresponding to the divisions of the Laboratory. In addition to the abstract text, the report number, investigator, AFML project monitor, contractor, contract number, AFML project/task number, report data and access numbers are given. Reports on research conducted by the AFML personnel as well as that conducted on contract are included.

ADVANCED DEVELOPMENT DIVISION (AFML/LC)

REPORT NO: AFML-TR-71-41 Volumes I, V, VI
ACCESS NO: 65,439 April 1973
TITLE: ADVANCED COMPOSITE TECHNOLOGY
FUSELAGE PROGRAM VOLUMES I, V, AND VI
AUTHOR(S): B. E. Kaminski; E. H. Swazey; J. A. Fant;
F. O. Olson; R. H. Roberts
CONTRACT NO: F33615-69-C-1494
CONTRACTOR: General Dynamics
PROJECT MONITOR: L. G. Kelly and W. R. Johnston (AFML/LC)
ABSTRACT: Volume I contains process information, acceptance-
type data, and engineering test data on laminates fabricated from three
basic types of advanced composite materials: graphite-epoxy, boron-epoxy,
and boron-aluminum. The development of tube fabrication and testing
techniques suitable for determining material properties of the basic uni-
directional lamina is described. Also presented are static and fatigue
test techniques suitable for determining strength properties of composite
laminates subjected to combined bending and shear loadings.

The research and development activity reported in Volumes V and VI covers the manufacturing technology developed for the advanced composite F-5 mid-fuselage component. The objectives of this effort were to develop the methods and techniques to manufacture the composite component. The unishell design concept coupled with the application of advanced materials required new methods and techniques for manufacturing. Descriptions of the design, tooling, and fabrication development and the entire component fabrication, inspection, costs and repairs are included. Detailed explanations are made of processes and techniques developed during the program.

REPORT NO: AFML-TR-72-278
ACCESS NO: 201,550 March 1973
TITLE: ADVANCED COMPOSITE APPLICATIONS FOR
SPACECRAFT AND MISSILES FINAL REPORT
AUTHOR(S): J. D. Forest; M. Varlas
CONTRACT NO: F33615-70-C-1442
CONTRACTOR: General Dynamics Corporation
PROJECT MONITOR: R. L. Rapson (AFML/LC)
PROJECT NO: 6169 CW
ABSTRACT: The objective of this program was to develop the technology necessary to design, fabricate, and test flightworthy missile and spacecraft structures utilizing advanced composite materials. Four flight configured, full-scale components were designed and fabricated under this program, and three of the structures met or exceeded all design criteria. The graphite/epoxy components demonstrated very precise thickness, finish, and dimensional control, and the finished part weights were very close to the predicted values. The adapter structure, the largest of the components, was actually a few pounds lighter than predicted, indicating that the 10-pound contingency weight originally included could be reduced. The detailed cost history of the graphite adapter indicates that this component was about 2.4 times the cost of the first aluminum article, but this cost increase would be more than offset by the payload value of weight saved. In a production run of at least 20-30 articles, where the high initial tooling can be amortized, the cost spread between the two materials decreases substantially, and major system cost savings are possible.

REPORT NO: AFML-TR-73-3 AD 907 449L
ACCESS NO: 201,551 February 1973
TITLE: CONCEPTUAL DESIGN OF COMPOSITE
V/STOL TACTICAL FIGHTER
AUTHOR(S): O. E. Dhonau; E. G. Blosser
CONTRACT NO: F33615-72-C-2134
CONTRACTOR: LTV Aerospace Corporation
PROJECT MONITOR: D. A. Roselius (AFML/LC)
PROJECT NO: 698 CW
ABSTRACT: This report describes "Conceptual Design of Composite V/STOL Tactical Fighter." A baseline aircraft of vectored thrust vertical take-off capability was selected. The aircraft major components were then redefined as composite concepts. A large group of wing, fuselage, and nacelle concepts were subjected to a systematic process of elimination from which a single concept for each component survived. From these data, a parametric analysis which resized the airplane was generated and documented. As a result of the potential payoff established by the study, development plans for a nacelle-inlet section, a fuselage barrel section, and a main wing structural box were prepared.

AFML/LC

REPORT NO: AFML-TR-73-4 AD 909 197L
ACCESS NO: 200,705 February 1973
TITLE: CONCEPTUAL DESIGN OF ADVANCED
COMPOSITE AIRFRAMES
AUTHOR(S): J. A. Fant
CONTRACT NO: F33615-72-C-1424
CONTRACTOR: General Dynamics
PROJECT MONITOR: E. H. Jaffe (AFML/LC)
PROJECT NO: 698 CW
ABSTRACT: The primary objectives of the research reported here were (1) to identify innovative design concepts for the application of advanced composite materials to airframe designs and (2) to assess the potential payoffs in terms of performance improvements and cost reductions resulting from these concepts. An additional objective was to determine the synergistic effects of coupling advanced composites with other emerging technologies to investigate further cascading of the payoffs available from composites. The study was conducted in two phases, Replacement Design and Conceptual Design, and General Dynamics Lightweight Fighter (LWF) was used as the conventional material baseline vehicle.

REPORT NO: AFML-TR-73-10 AD 909 367L
ACCESS NO: 201,388 March 1973
TITLE: CONCEPTUAL DESIGN OF ADVANCED
PROPULSION SYSTEMS
AUTHOR(S): J. L. Jack
CONTRACT NO: F33615-72-C-2067
CONTRACTOR: The Garret Corporation
PROJECT MONITOR: W. J. Schulz (AFML/LC)
PROJECT NO: 698 CW
ABSTRACT: This document describes a composite compressor design program entitled "Conceptual Design of Advanced Composite Propulsion Systems." It is concerned with the application of advanced composite materials in the design of both a coaxial compressor and a centrifugal compressor. This composite compressor would be capable of 2000 feet per second tip speeds and would be applicable to small engines.

AFML/LC

REPORT NO: AFML-TR-73-13 AD 911 917L
ACCESS NO: 69,663 June 1973
TITLE: COMPOSITE BOX BEAM OPTIMIZATION.
EXPERIMENTAL DATA SUPPORTING TECHNIQUE
DEVELOPMENT AND PRELIMINARY DESIGN
AUTHOR(S): P. J. Donohoe; E. L. Mathisen
CONTRACT NO: F33615-71-C-1605
CONTRACTOR: Grumman Aerospace
PROJECT MONITOR: R. L. Rapson (AFML/LC)
ABSTRACT: This report presents the experimentally determined characteristics and properties of boron/aluminum, graphite/epoxy and boron/epoxy composite materials. Included are the results of testing in support of activities to optimize the stepped press diffusion bonding process of boron/aluminum fabrication; the determination of basic laminate properties; verification of design and analysis methods; determination of the strength of bolted, brazed and/or bonded joints; and the environmental and fatigue resistance of the three composite materials. The test results obtained confirmed the selection of materials and fabrication processes for the Composite Beam Optimization program, and provided the required design allowable data.

REPORT NO: AFML-TR-73-40 Volume I AD 910 273L
ACCESS NO: 201,460 March 1973
TITLE: HIGH ALTITUDE ADVANCED
COMPOSITE DRONE
AUTHOR(S): R. G. Cheatham; R. B. Brown; S. N. Paterson
CONTRACT NO: F33615-72-C-2135
CONTRACTOR: The Boeing Aerospace Company
PROJECT MONITOR: E. H. Jaffe (AFML/LC)
PROJECT NO: 698 CN
ABSTRACT: This report describes the preliminary concept selection of a high altitude composite drone. Various conceptual designs are presented and these are backed up by the loads and stress analyses necessary to make them practical. Methods of manufacture are discussed and illustrated, showing the feasibility of the designs. Aerodynamics and weights analyses are presented as are the corresponding comparisons of the high altitude composite drone versus a drone made of conventional metal structure.

AFML/LC

REPORT NO: AFML-TR-73-57 AD 910 069L
ACCESS NO: 69,196 March 1973
TITLE: COMPOSITE WING CONCEPTUAL DESIGN
AUTHOR(S): W. D. Nelson
CONTRACT NO: F33615-71-C-1340
CONTRACTOR: McDonnell Douglas Corporation
PROJECT MONITOR: D. A. Roselius (AFML/LC)
PROJECT NO: 698 CW
ABSTRACT: Design, analysis, fabrication and test work are described which were performed to identify and develop the potentials of the advanced composite truss web wing box concept. The aircraft on which the effort is based is the Advanced Medium STOL Transport (AMST). A weight savings of 36.6% with respect to the metal wing box is achieved for the baseline truss web utilizing a boron-epoxy tapered sandwich lower cover and cutout-lightened substructure. A multi-rib/multi-web design optimization study is reported. Finite anisotropic element analyses for the wing and final test component are described. Laminate tests utilizing mixed graphite materials are described. Element and subcomponent tests are conducted to verify features of the design, including the fillet bond concept for joining webs to covers. The testing effort culminates in a sweep-break wing-fuselage intersection component which includes a stress-relieved bolted upper cover and a fillet-bonded lower cover. It achieves 94% of ultimate combined bending and torsion load. The major design features under test are validated since failure occurs in a conventional locally overstressed area.

REPORT NO: AFML-TR-73-160 AD 913 266L
ACCESS NO: 78,291 July 1973
TITLE: RELIABILITY OF COMPLEX LARGE SCALE
COMPOSITE STRUCTURE - PROOF OF CONCEPT
AUTHOR(S): M. E. Waddoups; R. V. Wolff; D. J. Wilkins
CONTRACT NO: F33615-70-C-2060
CONTRACTOR: General Dynamics Corporation
PROJECT MONITOR: R. M. Neff (AFML/LC)
ABSTRACT: A twelve month investigation was performed to develop a test laboratory facility for performing fatigue tests simulating real service loading and environmental conditions on composite structures. The closed-loop laboratory facility was evaluated using full-scale adhesively bonded step-lap joints, which simulated a composite-to-metal skin splice of a flight-test wing. The loading and temperature exposures were accomplished by storing proper commands on a digital magnetic tape that was converted in the laboratory to the necessary analog signals. Empirical data generated permitted the comparison of real-time and accelerated-time fatigue spectra, ambient and service temperature conditions, and the effects of humidity exposure on high-temperature joint strength.

AFML/LC

REPORT NO: AFML-TR-73-162 Volume I AD 915 591L
Volume II AD 915 592L
ACCESS NO: 201,620 July 1973
TITLE: QUALITY ASSURANCE FOR ADVANCED
COMPOSITE AIRCRAFT STRUCTURES
AUTHOR(S): L. R. Sanders
CONTRACT NO: F33615-71-C-1359
CONTRACTOR: McDonnell Douglas Corporation
PROJECT MONITOR: R. M. Neff (AFML/LC); G. E. Husman (AFML/MB)
PROJECT NO: 6169 CW
ABSTRACT: The objective of this program was to provide a
basis for demonstrating the structural integrity of a composite empennage-
type structure, characterized as full-depth honeycomb core which is sand-
wiched between composite laminate skins. Confidence in the structural
integrity of this composite structural aircraft component can be inferred
from the validity of quality assurance procedures and from the adequacy of
nondestructive testing (NDT) techniques. The first volume of this report
contains a detailed description of the entire program. The second volume is
a quality assurance manual which provides in detail all the necessary pro-
cedures for the fabrication and inspection of structurally sound composite
empennage components.

METALS AND CERAMICS DIVISION (AFML/LL)

REPORT NO: AFML-TR-72-124
ACCESS NO: 201,379 January 1973
TITLE: RESPONSE OF GLASS FIBER REINFORCED
EPOXY SPECIMENS TO HIGH RATES OF
TENSILE LOADING
AUTHOR(S): A. F. Armenakas; C. A. Sciammarella
CONTRACT NO: F33615-71-C-1533
CONTRACTOR: Polytechnic Institute of Brooklyn
PROJECT MONITOR: T. Nicholas; M. J. Sever (AFML/LLN)
PROJECT NO: 7351
TASK NO: 735106
ABSTRACT: The object of this investigation is to establish
experimentally the mechanical properties, and the mode of failure of glass
fiber-reinforced epoxy plates subjected to high rates of strain (30,000 in/
in/min) in the direction of the fibers, on a specially designed impact load-
ing machine propelled by explosives. The results are correlated with
those obtained by testing glass, fiber-reinforced epoxy plates subjected to
various low rates of strain (0.0265 in/in/min, 0.66 in/in/min, and
26.5 in/in/min).

REPORT NO: AFML-TR-72-272 AD 759 830
ACCESS NO: 201,386 February 1973
TITLE: PROJECT THEMIS METAL DEFORMATION
PROCESSING
AUTHOR(S): H. Conrad; M. Doner
CONTRACT NO: F33615-69-C-1027
CONTRACTOR: University of Kentucky
PROJECT MONITOR: A. M. Adair (AFML/LLM)
PROJECT NO: 7912
ABSTRACT: Uniaxial tension tests on Ti-50A indicated that
(a) dynamic strain aging occurred in the temperature range of 650° to
875° K with activation energies of 52 and 48 Kcal/mole for the maximum in
strain hardening rate and the minimum in total elongation, respectively;
(b) above about 900° K the flow stress was described very well by Weertman's
model for high temperature deformation. The temperature and stress
fields, including the shear stresses at the billet-die interface, existing
during hot extrusion of Ti-6Al-4V were calculated. The dislocation struc-
ture which develops during hydrostatic extrusion of Ti-50A was investigated
using transmission electron microscopy.

AFML/LL

REPORT NO: AFML-TR-72-283
ACCESS NO: 201,262 January 1973
TITLE: EXPLORATORY DEVELOPMENT ON APPLICATION OF RELIABILITY ANALYSIS TO AIRCRAFT STRUCTURES CONSIDERING INTERACTION OF CUMULATIVE FATIGUE DAMAGE AND ULTIMATE STRENGTH

AUTHOR(S): I. C. Whittaker; S. C. Saunders
CONTRACT NO: F33615-71-C-1134
CONTRACTOR: The Boeing Company
PROJECT MONITOR: R. C. Donat (AFML/LLN)

ABSTRACT: An analysis method for determining the reliability of airplane structures, subjected to the cumulative and maximum operational loads and the resultant interaction of fatigue damage and strength, has been investigated. The design variables include the central tendency values of the fatigue performance, that is, the average lives to initiation and the growth of a major crack, and the effect of the crack on structural strength. Other variables include the standard operational procedure of periodic inspection of the structure and its repair when found to be damaged. Functions, based on the length of the fatigue crack, are used to describe both the residual strength of the structure and the probability of the crack being detected and the cracked structure being repaired. The times to initiation of a crack and the later time when the crack becomes critical, i. e., unstable, are taken as random variables. The derived reliability model considers that at any time the structure is either failed or unfailed. If unfailed the structure may be uncracked, or cracked and undetected, or detected and repaired.

REPORT NO: AFML-TR-73-2 AD 768 447
ACCESS NO: 201,385 January 1973
TITLE: GROWTH OF TITANIUM AND CHROMIUM STRENGTHENED SAPPHIRE FIBERS

AUTHOR(S): J. S. Haggerty
CONTRACT NO: F33615-72-C-1956
CONTRACTOR: Arthur D. Little, Inc.
PROJECT MONITOR: R. L. Crane (AFML/LLC)

PROJECT NO: 7351
TASK NO: 735107

ABSTRACT: Pore-free Ti^{+3} and Cr^{+3} doped Al_2O_3 fibers were grown by the Arthur D. Little fiber growth process. The absence of surface and bulk defects in these fibers resulted in higher virgin and abraded room temperature strengths than comparable fibers produced by Tyco's Edge-Defined Film-Fed process. Solution hardening by Cr^{+3} doping resulted in improved high temperature tensile strengths. The high temperature strength increase with a Cr content, so further improvements are probable with higher doping levels.

REPORT NO: AFML-TR-73-12 AD 763 121
 ACCESS NO: 68,388 March 1973
 TITLE: BERYLLIUM IMPROVEMENT PROGRAM
 AUTHOR(S): R. L. Greene; G. B. Pinkerton
 CONTRACT NO: F33615-70-C-1585
 CONTRACTOR: Lockheed Missiles & Space Company, Inc.
 PROJECT MONITOR: K. L. Kojola (AFML/LLM)
 PROJECT NO: 627A
 ABSTRACT: A program was conducted to investigate and to define the material or/process variables which must be controlled in order to optimize the short time compression creep behavior of hot-pressed beryllium at 1500^o to 1800^oF. The program goal was to develop a commercially feasible material with improved creep resistance but without significant sacrifice of other mechanical properties. Materials were studied and characterized by compression creep tests, room and elevated temperature (300^o-500^oF) tensile tests, medium strain rate tensile tests, chemistry, grain size, microstructural constituents and salient process parameters. It was shown that maintaining low impurity levels, particularly of the elements, Mg, Si, and Al and developing a fine, uniform distribution of BeO in fine-grained beryllium led to improved creep resistance at 1800^oF.

REPORT NO: AFML-TR-73-16
 ACCESS NO: 200,237 December 1972
 TITLE: DEVELOPMENT OF COMPUTERIZED MICRO-STRUCTURE CONTROL PROCEDURE FOR Ti-6Al-2Sn-4Zr-6Mo ALLOY PRODUCTION COMPRESSOR DISKS
 AUTHOR(S): D. L. Ruckle; M. P. Smith
 CONTRACT NO: F33615-71-C-1569
 CONTRACTOR: Pratt & Whitney Aircraft Division
 PROJECT MONITOR: L. R. Bidwell (AFML/LL)
 PROJECT NO: 7351
 TASK NO: 735105
 ABSTRACT: Room temperature mechanical property tests including tensile, notched time fracture, plane strain fracture toughness, and strain controlled low cycled fatigue were performed on the Ti-6Al-2Sn-4Zr-6Mo (Ti-6-2-4-6) alloy. Two types of metallographic procedures for micro-examination of the alloy were developed. Processing and heat treatment variations were employed to produce thirty different micro/macro structural conditions in addition to ten heats taken from standard production forgings for the purpose of providing a wide range of structures for computer analysis. During the course of the contract, transparencies of the microstructures presented herein were supplied to AFML for this analysis.

AFML/LL

REPORT NO: AFML-TR-73-18 AD 759 557
ACCESS NO: 201,390 April 1973
TITLE: HIGH STRENGTH ALUMINUM
ALLOY DEVELOPMENT
AUTHOR(S): D. S. Thompson
CONTRACT NO: F33615-69-C-1643
CONTRACTOR: Reynolds Metals Company
PROJECT MONITOR: T. M. F. Ronald (AFML/LL)
ABSTRACT: RX720 alloy, nominally 6.75%Zn, 2.5%Mg, 1.2%Cu
and 0.12%Zr, has been evaluated in the form of 3" plate and 8" x 9" cross
section hand forgings. After various aging practices, it was evaluated in
terms of strength and electrical conductivity. These materials were then
evaluated and compared to 7075-T6. Fatigue strength appeared to be
slightly improved. The stress corrosion resistance of the forgings is
encouraging since no failures have occurred after 60 days testing. It was
recommended that the copper level should be increased slightly to 1.6%
in order to improve stress corrosion performance.

REPORT NO: AFML-TR-73-25 AD 762 302
ACCESS NO: 201,384 March 1973
TITLE: PLASTIC DEFORMATION OF C-AXIS
SAPPHIRE FILAMENTS
AUTHOR(S): R. E. Tressler; D. J. Barber
CONTRACT NO: F33615-71-C-1606
CONTRACTOR: University of Essex
PROJECT MONITOR: D. A. Rice
PROJECT NO: 7351
ABSTRACT: The yielding and flow behavior in uniaxial, con-
stant strain rate tensile tests of single crystal sapphire filaments oriented
with the tensile axis parallel to the filament axis was studied in the temper-
ature range from 1760°C to 1875°C. The existence of a strain-aging effect
leading to non-reproducible upper yield points was established. The
apparent activation enthalpies calculated from constant temperature
experiments reflect a flow stress dependence on temperature which includes
both substructure and deformation mechanism temperature dependencies.
The preliminary activation enthalpies calculated from differential tempera-
ture and differential strain rate experiments (constant structure experi-
ments) compare with the value for defect diffusion in sapphire, 80 Kcal/mole.

AFML/LL

REPORT NO: AFML-TR-73-34 AD 766 328
ACCESS NO: 69,427 May 1973
TITLE: COMPARISON OF ALUMINUM ALLOY 7050,
7049, MA52 AND 7175-T736 DIE FORGINGS

AUTHOR(S): J. T. Staley
CONTRACT NO: F33615-69-C-1644
CONTRACTOR: Alcoa
PROJECT MONITOR: T. M. F. Ronald (AFML/LLS)

ABSTRACT: Die forgings in Al alloys 7050, 7049, and MA52 were fabricated and evaluated for resistance to stress-corrosion cracking, quench sensitivity, and fracture toughness. In addition, all Alcoa data on the properties were collated. Stress-corrosion resistances were evaluated using the severest combinations for forging type and test conditions. All of these newer alloys were less quench sensitive than alloy 7075 and all developed better combinations of resistance to stress-corrosion cracking and fracture toughness than 7075-T6 and 7079-T6 at equal strengths. Because it developed the best combination of properties, alloy 7050 is a preferred selection for use as die forgings of relatively heavy section thickness for the aerospace industry. Special process 7175 is an equally good selection for die forgings of thin to moderate section thickness.

REPORT NO: AFML-TR-73-36 AD 759 828
ACCESS NO: 201,552 March 1973
TITLE: FAST FREEZING AS A METHOD FOR
ALUMINUM ALLOY DEVELOPMENT

AUTHOR(S): W. Rostoker; R. Dudek; C. Freda; R. Russell
CONTRACT NO: F33615-70-C-1525
CONTRACTOR: University of Illinois
PROJECT MONITOR: W. R. Kerr
PROJECT NO: 7351
TASK NO: 735108

ABSTRACT: It is shown that the atomization process generates sufficiently high freezing rates to suppress within limits the primary crystallization of intermetallic compounds and the secondary crystallization of eutectic. The resultant structures are probably supersaturated solid solutions. Thus, for example, alloying aluminum with as much as 5% Mn and 3% Cr, respectively, is practical. It is shown that Al-Mn-Cu and Al-Mn-Cr-Mg-Zn alloys produced from consolidated powder can generate high tensile yield strengths and hardnesses which resist softening at temperatures as high as 350°C. Some alloys show good hot yield strengths. Hot forming techniques will be necessary for fabrication. Preliminary tests indicate that these alloys are not susceptible to stress-corrosion cracking at stresses of yield strength magnitude.

AFML/LL

REPORT NO: AFML-TR-73-37 AD 759 215
ACCESS NO: 201,358 April 1973
TITLE: DEVELOPMENT OF A 900F
TITANIUM ALLOY
AUTHOR(S): G. S. Hall; S. R. Seagle; H. B. Bomberger
CONTRACT NO: F33615-71-C-1551
CONTRACTOR: RMI Company
PROJECT MONITOR: R. F. Geisendorfer (AFML/LLN)
ABSTRACT: The purpose of this investigation was to develop a titanium alloy for applications at 900F. The main target goal was to achieve an improved combination of elevated temperature properties, particularly high elevated temperature tensile strength. The alloy Ti-5Al-5Sn-2Zr-4Mo-0.25Si comes close to meeting the objectives of the contract. This alloy has the capability of achieving 120 ksi 900F yield strength and high creep strength. Preliminary tests were also conducted on the effect atmospheric surface contamination has on the creep behavior of high temperature titanium base alloys. Material tested in air at 1100F was found to creep at an appreciably higher rate than when tested in argon at same temperature and stress.

REPORT NO: AFML-TR-73-45
ACCESS NO: 201,585 February 1973
TITLE: RESPONSE OF MATERIALS TO
IMPULSIVE LOADING
AUTHOR(S): T. W. Lee; H. F. Swift; D. D. Preonas; P. W.
Dueweke; R. S. Bertke
CONTRACT NO: F33615-73-C-5027
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: A. K. Hopkins (AFML/LLN)
PROJECT NO: 7360
TASK NO: 736006
ABSTRACT: During the period of Contract No. F33615-70-C-1228, the University of Dayton Research Institute (UDRI) carried out six major studies including Hypervelocity Impact, Planar Impact, Ballistic Velocity Impact Testing, Pebble Impact, Rain Erosion, and Foreign Object Damage. In the Hypervelocity Impact studies the effects of material strength properties on crater growth were examined in thick targets, also the peak normal stress behind the shock wave was measured as a function of distance and angle. The response of thin targets to hypervelocity impact was examined as a function of the residual state of the debris material. Planar impact by explosive driven flyer plate was used to describe the behavior of shock loaded material in the presence of a phase change. Initial laboratory investigations of Foreign Object Damage (FOD) to simulated aircraft compressor blades are described.

REPORT NO: AFML-TR-73-49 AD 761 515
ACCESS NO: 200,271 April 1973
TITLE: DEVELOPMENT OF A FORMABLE SHEET
OF TITANIUM ALLOY
AUTHOR(S): H. W. Stemme
CONTRACT NO: F33615-71-C-1682
CONTRACTOR: Lockheed-Georgia Co.
PROJECT MONITOR: R. F. Geisendorfer (AFML/LLM)
ABSTRACT: The objective of this program was to develop a metastable beta titanium sheet alloy which could be formed by standard sheet metal shop equipment and then reliably heat treated to a high strength level. It is anticipated that such an alloy will reduce initial manufacturing costs by eliminating costly hot-forming operations and by allowing greater field repair capability. Such an alloy composition was developed. It, however, did not exhibit the desired high cold formability and was not heat treatable to a high strength level with usable ductility and toughness. An alloy of a composition that resulted in cold deformation by slip exhibited a better balance of cold formability and mechanical properties after heat treatment. The alloy was Ti-3Al-1.5V-3Cr-3Sn. A secondary objective was the study of compositional effects as related to solutionizing cycle, cooling rate, deformation mode and heat treat response. Nineteen alloy compositions were investigated.

REPORT NO: AFML-TR-73-56 AD 761 814
ACCESS NO: 201,459 March 1973
TITLE: COMPUTER ANALYSIS OF ALLOY SYSTEMS
AUTHOR(S): L. Kaufman; H. Nesor
CONTRACT NO: F33615-71-C-1471
CONTRACTOR: Manlabs, Incorporated
PROJECT MONITOR: L. R. Bidwell (AFML/LLM)
PROJECT NO: 7353
TASK NO: 735302
ABSTRACT: Computer analysis of twenty-three binary and thirteen ternary titanium and columbium base systems has been performed in order to provide phase stability and thermochemical characterization data which can be used to define fabrication procedures for achieving high temperature stability and improved mechanical properties. M_s temperatures have been calculated for titanium base alloys with simultaneous additions of Mo, V, Al, Mn and Sn. The effect of zirconium on the solubility of Si and Be in hcp titanium was calculated along with the occurrence of miscibility gap formation in bcc titanium base systems. Titanium and columbium base ternary systems were analyzed to predict the temperature-composition trajectories of eutectoid and eutectic troughs and the location of melting point minima. A method was developed for calculation of the eutectic temperature and composition of metal alloy-metal carbide systems and applied to the (Fe, Ni, Cr) -TiC case.

AFML/LL

REPORT NO: AFML-TR-73-67 AD 764 769
ACCESS NO: 67,887 April 1973
TITLE: HIGH-TEMPERATURE ELECTROCHEMICAL
RESEARCH IN METALLURGY
AUTHOR(S): W. M. Boorstein; R. A. Rapp; G. R. St. Pierre
CONTRACT NO: F33615-70-C-1103
CONTRACTOR: Ohio State University
PROJECT MONITOR: H. B. Kirkpatrick (AFML/LLP)
PROJECT NO: AO 1466
ABSTRACT: Various types of novel high-temperature electro-chemical devices incorporating solid, oxygen ion-conducting electrolytes were designed, analyzed, and tested for potential application in research and industrial metallurgical processing. Devices for measurement and/or control of the thermodynamic activity of oxygen (and related non-metallic components) in stagnant or flowing gases and in solid and liquid metals; for the continuous coulometric deoxidation of molten metal streams; for the measurement of thermodynamic and kinetic parameters of metallurgical reactions; and for the determination of sulphur contents in molten alloys and slags were specifically investigated. Scientific data were obtained on the electrical conductivity characteristics of commercial solid oxide electrolyte materials; on the fundamental principles of operation of solid-electrolyte electrochemical cells as oxygen pumps, and on the diffusivity and solubility of oxygen in molten copper, silver, lead, and iron.

REPORT NO: AFML-TR-73-69 AD 760 174
ACCESS NO: 201,375 April 1973
TITLE: PROCEEDINGS OF THE INTERDISCIPLINARY
WORKSHOP ON NONDESTRUCTIVE TESTING-
MATERIALS CHARACTERIZATION
AUTHOR(S): D. O. Thompson
CONTRACTOR: North American Rockwell
PROJECT MONITOR: D. O. Thompson (AFML/LL)
PROJECT NO: 7351
TASK NO: 735109
ABSTRACT: The field of nondestructive testing and materials characterization is examined with emphasis on new approaches that may lead to significantly improved future capabilities. The presentations range from examples of present capabilities and limitations to fields of basic research. The recommendations of four panels are presented for future research and development to advance the present state-of-the-art.

AFML/LL

REPORT NO: AFML-TR-73-73 AD 770 027
ACCESS NO: 202,043 September 1973
TITLE: ON THE DETERMINATION OF CONSTITUTIVE
EQUATIONS FROM PLASTIC WAVE PROPAGATION PHENOMENA
AUTHOR(S): T. Nicholas
CONTRACTOR: Internal
PROJECT MONITOR: T. Nicholas (AFML/LLN)
PROJECT NO: 7351
TASK NO: 735106
ABSTRACT: Numerical results of a computer analysis are presented for two problems involving the propagation of plastic waves of uniaxial stress in long rods or bars. Characteristics of the wave propagation phenomena are determined for assumed materials which exhibit strain-rate dependent material behavior of the form proposed by Malvern, using the exponential form of the plastic strain rate function. The results are examined with regard to their uniqueness and sensitivity to the constitutive equation for cases involving the propagation of strain increments in a prestressed rod and for a suddenly applied constant velocity at the end of a long rod. Comparisons are made with predictions of the rate-independent theory of plastic wave propagation using both the static stress-strain curve and a single "dynamic" curve. The interpretation of experimental results in terms of a proposed constitutive law is discussed.

REPORT NO: AFML-TR-73-84 AD 764 355
ACCESS NO: 201,600 June 1973
TITLE: ELASTIC PROPERTIES OF BORON SUBOXIDE
AND THE DIAMETRICAL COMPRESSION
OF BRITTLE SPHERES
AUTHOR(S): D. R. Petrak; R. Ruh; W. B. Shook
CONTRACTOR: Internal
PROJECT MONITOR: Lt. Hollenberg G.W. (AFML/LLS)
PROJECT NO: 7350
TASK NO: 735001
ABSTRACT: The room temperature elastic moduli of hot pressed boron suboxide were determined in the 0-16% porosity range using the resonant sphere technique. Results revealed that Poisson's ratio was constant in this range and that Young's and shear moduli followed Hasselman's semiempirical relation with $E_0 = 68.5 \times 10^6$ psi and $A = 5.1$. High speed photographs of diametrically compressed glass spheres indicate that fracture initiates near the center of the sphere. Also a stress analysis of such a sphere shows that the maximum tensile stress occurs near the center of the sphere. Therefore a new test for the tensile strength of brittle materials is suggested which is not influenced by surface defects. The tensile strength of boron suboxide was determined using the diametrical compression test and values approximately 25% lower than four point bend tests were obtained.

AFML/LL

REPORT NO: AFML-TR-73-92 AD 764 775
ACCESS NO: 201,595 June 1973
TITLE: APPLICATION OF RELIABILITY ANALYSIS TO
AIRCRAFT STRUCTURES SUBJECT TO FATIGUE
CRACK GROWTH AND PERIODIC STRUCTURAL
INSPECTION
AUTHOR(S): I. C. Whittaker; S. C. Saunders
CONTRACT NO: F33615-71-C-1134
CONTRACTOR: Boeing Commercial Airplane Company
PROJECT MONITOR: R. C. Donat (AFML/LLN)
ABSTRACT: A method of simulating crack growth has been
investigated. The proposed model, which is based on linear elastic fracture
mechanics theory, allows for the variability in crack growth behavior found
in the experimental data for various materials. Given a reference stress
intensity factor range and central tendency values for the crack growth rate
and the exponent of the stress intensity factor excursions of a material in
a specified configuration, Monte Carlo simulation is used to select various
combinations of parameters. These are then used to generate fatigue
cracks, on the assumption that crack growth rate is a power function of
the stress intensity factor range. The residual strength of the cracked
structure is considered to be a decreasing function of the induced crack
length. The probability of crack detection also depends on the generated
crack and is assumed to improve with increasing crack length.

REPORT NO: AFML-TR-73-94 AD 762 546
ACCESS NO: 201,598 May 1973
TITLE: THE EKS-SQUARE TEST OF GOODNESS OF FIT -
AN IMPROVEMENT OF THE CHI-SQUARE TEST
AUTHOR(S): W. Weibull
CONTRACT NO: F44620-72-C-0028
CONTRACTOR: Waloddi Weibull
PROJECT MONITOR: W. J. Trapp (AFML/LL)
PROJECT NO: 7351
TASK NO: 735106
ABSTRACT: When applying the classical Chi-square test of
goodness of fit, it is always assumed that the test statistic is distributed.
Since this is true only for very large samples, some restrictions on the
class frequencies have to be introduced. It is generally accepted that none
of the expected frequencies should be less than ten, which makes this test
useless for small and moderate samples. In order to eliminate these -
from a practical viewpoint severe - restrictions, it is proposed to use the
exact sampling distribution instead of the limiting - distribution. When
doing so, the test will be called the Eks-square test.

REPORT NO: AFML-TR-73-95 AD 764 777
ACCESS NO: 201,591 May 1973
TITLE: THE CONCEPT OF SCORE OF A
RANDOM SAMPLE
AUTHOR(S): W. Weibull
CONTRACT NO: F44620-72-C-0028
CONTRACTOR: Waloddi Weibull
PROJECT MONITOR: W. J. Trapp (AFML/LL)
PROJECT NO: 7351
TASK NO: 735106
ABSTRACT: To any given random sample there may be assigned a number called its score and denoted by $SC(r, Nos)$, where r = the number of classes into which the space of the random variable has been divided and Nos = the number of order statistics actually used. It is easily determined from the sample elements and offers some definite advantages as a test statistic for selecting the most probable population from which the given sample has been drawn. Its decision power tends with increasing r to the largest power attainable for the given sample size. By means of some versatile computer programs the sampling distributions for several combinations of r and Nos have been determined. Tables have been prepared from which the probabilities of twelve different hypothetical populations can be immediately read and their acceptability stated.

REPORT NO: AFML-TR-73-97 AD 762 604
ACCESS NO: 201,555 May 1973
TITLE: A NEW TEST OPERATOR, VJ, BASED
ON CLASS FREQUENCIES
AUTHOR(S): W. Weibull
CONTRACT NO: F44620-72-C-0028
CONTRACTOR: Waloddi Weibull
PROJECT MONITOR: W. J. Trapp (AFML/LL)
PROJECT NO: 7351
TASK NO: 735106
ABSTRACT: A new test statistic, denoted by VJ, was introduced. It is defined by the number v_i of sample elements which fall within each of r properly defined classes into which the space of the variable x has been divided. The properties of VJ have been thoroughly examined. In particular the class limits yielding the largest decision power have been determined with the result that, in some cases, the decision power was found to be somewhat larger than anyone so far attained. The statistic VJ can also be used for stating whether a hypothetical distribution is acceptable or not and also for selecting the most probable one within a set of such distributions. Necessary tables for the practical use have been prepared.

REPORT NO: AFML-TR-73-98 AD 764 361
ACCESS NO: 201,594 July 1973
TITLE: THE CONCEPT OF PSEUDO-STANDARDIZED
VARIABLES AND ITS USE AS ELEMENTS OF
SHAPE OPERATORS
AUTHOR(S): W. Weibull
CONTRACT NO: F44620-72-C-0028
CONTRACTOR: Waloddi Weibull
PROJECT MONITOR: W. J. Trapp (AFML/LL)
PROJECT NO: 7351
TASK NO: 735106
ABSTRACT: The concept of pseudo-standardized variable is explained and the fundamental properties of this variable are indicated. Its most important property of being scale and location invariant makes it useful as elements of shape operators, and its space being equal to the closed interval has practical advantages. Four types of shape operators are defined and examined. Twenty-five tables which simplify their practical applications have been prepared and are presented. Two examples concerning data of rotating beam fatigue performance illustrate the different numerical procedures.

REPORT NO: AFML-TR-73-102 AD 769 265
ACCESS NO: 202,008 June 1973
TITLE: A LOAD CALIBRATION TECHNIQUE FOR USE
ON LARGE INDUSTRIAL PRESSES AND
SMALL TESTING MACHINES
AUTHOR(S): V. DePierre; S. O. Davis; F. J. Gurney
CONTRACT NO: F33615-71-C-1163
CONTRACTOR: Westinghouse Electric Company
PROJECT MONITOR: A. M. Adair (AFML/LLM)
PROJECT NO: 7351
TASK NO: 735108
ABSTRACT: A load calibration technique based on the plastic deformation of a ring specimen is described. The method is applicable to any size press at loads up to full capacity. The method consists of determining the true flow stress of a meat of material by compression of small ring specimens on a calibrated test machine and treating the geometric change of the ring mathematically. The geometric changes in the ring specimen and the previously determined flow stress are treated by the same mathematical analysis to determine the deformation pressure and thus the deformation load. A comparison is made of the calibration from the ring cell with other calibrations already determined on a mechanical crank press and a hydraulic extrusion press. The ring cell is shown to yield highly accurate loads.

REPORT NO: AFML-TR-73-103 AD 769 763
ACCESS NO: 202,022 June 1973
TITLE: HARDNESS, STRENGTH, AND ELONGATION
CORRELATIONS FOR SOME TITANIUM-BASE
ALLOYS
AUTHOR(S): D. J. Abson; W. A. Houston; T. E. Jones;
F. J. Gurney
CONTRACT NO: F33615-71-C-1163
CONTRACTOR: Westinghouse Electric Company
PROJECT MONITOR: A. M. Adair; V. DePierre (AFML/LLM)
PROJECT NO: 7351
TASK NO: 735108
ABSTRACT: Previously published results on aluminum-base
alloys and steels showed that accurate prediction of yield stress and ultimate
tensile stress was possible from hardness data. The present study was
undertaken to see if the relationships were also obeyed by Ti-base alloys.
The intention was to permit exploitation of the economic advantages which
would result from a saving in machining cost and in testing time, if the
judicious use of hardness testing were to provide data approximately equiva-
lent to that obtained by tensile testing. The agreement was only moderately
good for the Ti-13V-11Cr-3Al alloy, and was poor for the other two alloys.
After further analysis of the data, the breakdown of the correlation was
attributed to a different deformation mechanism, presumably micro-twinning,
occurring during hardness testing from that prevailing during tensile testing.
This effect also explains, for the materials in the present study, the break-
down of both the relationship between m and n, and (ii) the relationship which
involve stress/hardness ratios.

REPORT NO: AFML-TR-73-105 Part 1 AD 770 189
ACCESS NO: 202,006 July 1973
TITLE: PLASTIC DEFORMATION OF METALS AT HIGH
STRAIN RATES. PART I THE EFFECTS OF
TEMPERATURE ON THE STATIC AND DYNAMIC
STRESS-STRAIN CHARACTERISTICS IN TORSION
OF 1100-0 ALUMINUM
AUTHOR(S): A. M. Eleiche; J. Duffy
CONTRACT NO: F33615-71-C-1308
CONTRACTOR: Brown University
PROJECT MONITOR: T. Nicholas (AFML/LLN)
PROJECT NO: 7353
TASK NO: 735303
ABSTRACT: A series of tests is described in which tubular
specimens of a commercially pure polycrystalline aluminum were loaded in
torsion at one of two dynamic rates up to shear strains over a temperature
range -180C to 250C. The tests were performed in a modified torsional
split-Hopkinson bar. The experimental results give the flow stress in shear,

ABSTRACT (Cont'd): the strain and the strain rate against time and stress-strain curves which are compared to the corresponding "static" curves obtained by testing similar specimens in torsion. A graph showing the dependence of flow stress on temperature indicates that there are three different temperature ranges for polycrystalline aluminum within each of which a different deformation mechanism presumably dominates the flow process.

REPORT NO: AFML-TR-73-105, Part II AD 769 446
ACCESS NO: 202,007 July 1973
TITLE: PLASTIC DEFORMATION OF METALS AT HIGH STRAIN RATES. PART II STEADY-STATE CRACK PROPAGATION IN A PLATE SUBJECTED TO COMBINED BENDING AND TENSION
AUTHOR(S): A. F. Fossum; L. B. Freund
CONTRACT NO: F33615-71-C-1308
CONTRACTOR: Brown University
PROJECT MONITOR: T. Nicholas (AFML/LLN)
PROJECT NO: 7353
TASK NO: 735303
ABSTRACT: The dynamic stress intensity factor and energy release rate are determined for the configuration in which a semi-infinite, constant velocity crack is propagating in a finite plate subjected to pure bending about the direction of propagation. In addition, a constant extension at the edges of the plate is imposed in the direction normal to the direction of crack propagation. In one case, zero shear stress is imposed at the edges of the plate and, in another case, zero displacement is imposed at the edges of the plate in the direction of crack propagation. For the case of pure bending alone, the dynamic stress intensity factor is shown to be independent of crack velocity. The problems are formulated in terms of the Poisson-Kirchhoff theory of thin plates in which the Kirchhoff conditions for a free edge are applied. The stress intensity factors are solved for directly by application of Laplace transform methods, the Wiener-Hopf technique, and asymptotic analysis.

AFML/LL

REPORT NO: AFML-TR-73-107 AD 768 627
ACCESS NO: 201,704 March 1973
TITLE: EVALUATION OF THE RELIABILITY AND
SENSITIVITY OF NDT METHODS FOR
TITANIUM ALLOYS

AUTHOR(S): R. J. Lord
CONTRACT NO: F33615-72-C-1203
CONTRACTOR: McDonnell Douglas
PROJECT MONITOR: J. A. Holloway (AFML/LLN)
PROJECT NO: 7351
TASK NO: 735109

ABSTRACT: A program to improve NDT techniques is being sponsored by the AF. Several penetrant inspection parameters have been investigated. A full size Ti-6Al-4V ingot has been melted for use in the future NDT capability portion of the program. The melting procedure was intentionally altered to induce Type I and Type II alpha stabilized defects. The ingot has been converted to 9 inch billet, 6 inch billet, and finally bar and plate. Ultrasonic and radiographic inspections were made of the ingot, 9 inch diameter billet and 6 inch diameter billet. During the ultrasonic inspections of the ingot and billet, the effectiveness of the inspections were increased by using shear wave as well as longitudinal wave.

REPORT NO: AFML-TR-73-113 AD 764 731
ACCESS NO: 201,609 May 1973
TITLE: THERMAL AGING OF SILVER-PLATED
COPPER AIRCRAFT ELECTRICAL WIRE

AUTHOR(S): L. R. Bidwell
CONTRACTOR: Internal
PROJECT MONITOR: L. R. Bidwell (AFML/LL)
PROJECT NO: 7351

ABSTRACT: FEP/polyimide-insulated silver-plated copper aircraft electrical wire was thermally aged at temperatures of 150 - 230 C for periods of up to 1000 hrs. The wires were examined for evidence that the insulation contributed to strand blocking during high temperature exposure. No evidence for a reaction between the insulation and the metal conductors was found. The phenomenon can be attributed entirely to the interstrand diffusion of silver. Two types of conductor degradation, unrelated to strand blocking, were identified. The nature, possible cause, and probably effect of each is discussed and a change in the current temperature rating procedure is recommended.

REPORT NO: AFML-TR-73-123 AD 770 301
ACCESS NO: 201, 706 August 1973
TITLE: DETERMINATION OF FEASIBILITY OF APPLY-
ING COMPUTER ANALYSIS OF TITANIUM
ALLOY MICROSTRUCTURES TO QUALITY
CONTROL
AUTHOR(S): A. Dekaney; L. E. Guthrie
CONTRACT NO: F33615-71-C-1590
CONTRACTOR: Mead (Data Corporation)
PROJECT MONITOR: L. R. Bidwell (AFML/LL)
PROJECT NO: 7351
ABSTRACT: The objective of this effort was to determine the
feasibility of applying digital computer analysis of microstructures to
production quality control of titanium alloys. Two types of microstructure
samples were examined for the Ti-6Al-2Sn-4Zr-6Mo titanium alloy under
consideration. These included normal preparation of specimens and non-
destructive preparation through electropolishing and replication. The speci-
mens were computer analyzed to establish geometric properties of primary
alpha and secondary alpha particles. The success in predicting ultimate
tensile strength, yield strength, % of elongation, % of reduction in area,
fracture toughness, fatigue cycles to pinpoint crack indication and cycle
to 1/32 inch crack for three test specimens indicates a promising future
for the application of digital techniques to titanium alloy quality control.

REPORT NO: AFML-TR-73-125 AD 767 227
ACCESS NO: 200, 291 July 1973
TITLE: DEVELOPMENT OF A FILLER METAL AND
JOINING PROCESS FOR TITANIUM-ALLOY
HONEYCOMB PANELS
AUTHOR(S): J. R. Woodward
CONTRACT NO: F33615-71-C-1888
CONTRACTOR: Rohr Industries
PROJECT MONITOR: M. A. Greenfield (AFML/LLM)
PROJECT NO: 7351
TASK NO: 735102
ABSTRACT: The second generation beta titanium alloys, Beta
III, RMI 38-6-44 and TMCA 88-23, were furnished in foil and fabricated
into honeycomb core. All three alloys responded well to the core manu-
facturing process. Thermal effect studies showed that all of the beta
titanium alloys were relatively unaffected by high temperature, long time
exposures when in foil form. Sheet forms resulted in grain growth under
the same conditions. The Rohr Ind., Inc. proprietary LIDTM bonding
process showed the highest strength joints of all other systems tested.
Sandwich panels made with the three beta titanium cores bond to Ti, 6Al,
4V faces were measured in all sandwich test modes. The data were com-
pared with sandwich structure made with the same joining system except

ABSTRACT (Cont'd): with Ti, 3Al, 2.5V core. Results showed that significant strength improvements can be realized by using beta Ti core. Projections also show that material cost economies may be realized by using beta Ti core.

REPORT NO: AFML-TR-73-129 AD 770 108
 ACCESS NO: 202,023 June 1973
 TITLE: NONDESTRUCTIVE DETERMINATION OF
 SURFACE FLAW GEOMETRY BY ACOUSTICAL
 HOLOGRAPHY EXPLORATORY DEVELOPMENT
 AUTHOR(S): M. E. Fourney; D. C. Auth; M. J. Intlekofer;
 A. S. Kobayashi
 CONTRACT NO: F33615-72-C-1204
 CONTRACTOR: Aerospace Research Lab
 PROJECT MONITOR: J. W. Bohlen; A. F. Grandt (AFML/LL)
 PROJECT NO: 7351
 ABSTRACT: The results of experiments aimed at developing a new nondestructive method of investigating surface flaw geometry based on acoustical holography and a newly proposed liquid crystal read-out device are presented. The liquid crystal area detector was shown to be feasible for use with acoustical holography; however, it was not applied to the monitoring of surface flaw geometry. The method was shown to have an order of magnitude improvement in resolution capabilities. However, it was bound to be severely lacking in the area of sensitivity, response time, and dynamic range. A strict thermal activation of the liquid crystals by the ultrasound was found not to be the optimum.

REPORT NO: AFML-TR-73-131 AD 763 785
 ACCESS NO: 201,618 June 1973
 TITLE: SOLID SOLUTION STRENGTHENING AND DIS-
 PERSION HARDENING IN DILUTE TITANIUM
 ALLOYS
 AUTHOR(S): T. Sakai; M. E. Fine
 CONTRACT NO: F33615-71-C-1252
 CONTRACTOR: Northwestern University
 PROJECT MONITOR: S. Fujishiro (AFML/LLS)
 PROJECT NO: 7351
 TASK NO: 735103
 ABSTRACT: The mechanical properties of Ti-Al single crystals up to 5.2 at % Al were measured by transmission electron microscopy. Solid solution softening was observed in dilute alloys for both prismatic and basal slip and attributed to scavenging of interstitials. Schmid's critical resolved shear stress law doesn't hold for prismatic slip in dilute Ti-Al alloys, the CRSS varies with orientation. The amount of failure decreases as the temperature is raised and as the Al content is increased. The ratio of CRSS for basal slip to prismatic slip decreases with increase in Al.

ABSTRACT (Cont'd): Mostly screw dislocations remain after small deformation at low temperatures and the screw component increases with % Al. However, in low Al alloys with high interstitial contents most of the remaining dislocations are edges. The practical significance of the results are discussed.

REPORT NO: AFML-TR-73-133
ACCESS NO: 202,335 July 1973
TITLE: QUANTUM DETECTION OF ULTRASONIC
ELECTRON SPIN INTERACTION
AUTHOR(S): A. H. Francis
CONTRACT NO: F33615-72-C-1783
CONTRACTOR: University of Illinois
PROJECT MONITOR: M. J. Buckley (AFML/LLP)
ABSTRACT: The optically detected acoustic paramagnetic resonance of the metastable triplet state of 1, 2, 4, 5-tetrachlorobenzene in zero field is reported. An elementary discussion of the phenomenon is presented along with a description of the experimental technique.

REPORT NO: AFML-TR-73-146 AD 770 217
ACCESS NO: 202,051 July 1973
TITLE: THE EVALUATION OF ACOUSTIC IMPACT
TECHNIQUE FOR DETECTION OF INCIPIENT
CRACKS IN AIRCRAFT COMPONENTS
AUTHOR(S): R. H. Bickford; G. V. Demchak; J. J. Sciarra
CONTRACT NO: F33615-71-C-1769
CONTRACTOR: Boeing
PROJECT MONITOR: J. W. Bohlen (AFML/LLN)
ABSTRACT: The need for a reliable method for detection of incipient cracks near or under fasteners in aircraft structures is well known. The objective of this program is to permit or preclude the utilization of this technique as a field inspection tool. Investigations were completed which indicated that the AIT system is not a feasible tool for the detection of incipient cracks in aircraft components.

REPORT NO: AFML-TR-73-150
ACCESS NO: 201,703 May 1973
TITLE: EVALUATION OF STRUCTURAL RELIABILITY
ANALYSIS PROCEDURES AS APPLIED TO
FIGHTER AIRCRAFT
AUTHOR(S): L. F. Impellizzeri; A. E. Siegel; R. A. McGinnis
CONTRACT NO: F33615-72-C-1882
CONTRACTOR: McDonnell Douglas
PROJECT MONITOR: R. C. Donat (AFML/LLD)
PROJECT NO: 7351
TASK NO: 735106
ABSTRACT: Structural reliability analysis procedures were evaluated for estimating the variability in fighter aircraft fatigue performance. The expected magnitude of this variability was determined based on an investigation of scatter in fatigue test results for aluminum structures. The Weibull probability distribution provides a better fit of the spectrum fatigue data than the log-normal. The alpha value was determined from 1060 spectrum test results of which 243 were full scale airplane and airplane component tests. These included the F-3H Demon wing and horizontal tail, the F-4 Phantom II wing box beam, the Lockheed wing test panel, the F-9F Panther wing, the Navy Lab box beam, the P-51 Mustang wing, the C-46 transport wings and the British Piston Provost wing. Probable minimum service lives considering the F-4 fleet size and individual airplane usage were computed based on the Weibull based scatter factor and order statistics.

REPORT NO: AFML-TR-73-157
ACCESS NO: 202,087 May 1973
TITLE: DEVELOPMENT AND APPLICATION OF NON-DESTRUCTIVE METHODS FOR PREDICTING MECHANICAL PROPERTIES OF ADVANCED REINFORCED NONMETALLIC COMPOSITES
AUTHOR(S): C. H. Hastings; E. F. Olster; S. A. Lopilato
CONTRACT NO: F33615-70-C-1526
CONTRACTOR: AVCO
PROJECT MONITOR: W. L. Shelton (AFML/LLN)
PROJECT NO: 7351
TASK NO: 735109
ABSTRACT: This report concerns itself with a detailed evaluation and development of ultrasonic interval velocity measurement technique. Results indicate that it is a practical and powerful tool applicable to the evaluation of boron/epoxy laminates for structural hardware components. Best results are achieved in the 0 and 90 degree directions of the laminates studied. Unbalanced laminates lead to greater errors in the 45 direction. Based on interval velocity measurements, correlations have been developed

ABSTRACT (Cont'd): for modulus calculation and tensile strength prediction. Degradation of boron/epoxy laminates studied, because of prior tensile loading, did not exist.

REPORT NO: AFML-TR-73-170
 ACCESS NO: 202,143 October 1973
 TITLE: MULTIAXIAL RESPONSE OF ATJ-S GRAPHITE
 AUTHOR(S): J. Jortner
 CONTRACT NO: F33615-72-C-2047
 CONTRACTOR: McDonnell Douglas
 PROJECT MONITOR: G. W. Hollenberg (AFML/MXS)
 PROJECT NO: 7381
 TASK NO: 738102
 ABSTRACT: Experiments to explore the fracture and deformation of ATJ-S graphite under multi-axial stresses are described. The program included additional fracture tests in biaxial tension at 2,000F; an analytical evaluation of the applicability and limitations of biaxial test data; tests at room temperature under triaxial stress and some biaxial experiments at room temperature. The 2000F fracture data suggest that biaxiality in tension causes a relatively greater decrease in stress at failure at 2000F than at room temperature; however the results are clouded by the possibility that a defective billet was used in the tests. Based on analysis, previous effort has been reviewed and revised summary plots of biaxial fracture suggest that an ellipsoidal yield function and a "non-associated" flow rule describe the measured strain responses of ATJ-S graphite better than some alternate approaches. The triaxial data also illustrate the potentially large effects that stress history can have on strain. The biaxial softening experiments demonstrate the existence of a negative incremental Poisson's ratio in biaxial tension.

REPORT NO: AFML-TR-73-177 AD 770 754
 ACCESS NO: 202,069 July 1973
 TITLE: PLASTIC SHEAR PROPERTIES OF METALS AND ALLOYS AT HIGH STRAIN RATES
 AUTHOR(S): M. C. C. Tsai; J. D. Campbell
 CONTRACT NO: AF-AFOSR-71-C-2056
 CONTRACTOR: Oxford University
 PROJECT MONITOR: T. Nicholas (AFML/LLN)
 PROJECT NO: 7351
 TASK NO: 735106
 ABSTRACT: An account is given of experiments using a torsional split Hopkinson bar apparatus, by means of which short tubular specimens can be subjected to shear strain rates up to 3000 sec⁻¹. The methods of calibration and data reduction are described, and static and dynamic shear properties are given for mild and stainless steel, titanium, copper, yellow brass and aluminum. Some of the results are compared with existing data

ABSTRACT (Cont'd): obtained in shear, tension and compression tests on similar materials, and the significance of the observed rate dependence of the flow stress is briefly discussed.

REPORT NO: AFML-TR-73-178
 ACCESS NO: 202,070 May 1973
 TITLE: THE MECHANICAL BEHAVIOR OF METAL
 MATRIX COMPOSITES
 AUTHOR(S): S. T. Scheirer
 CONTRACT NO: F33615-72-C-1601
 CONTRACTOR: TRW, Incorporated
 PROJECT MONITOR: K. D. Shimmin (AFML/LLN)
 PROJECT NO: 7351
 TASK NO: 735106
 ABSTRACT: A study of certain factors influencing tensile, fatigue, and creep behavior in B-Al and B/SiC-Ti composite materials was performed. The effects of controlled composite imperfections on tensile and fatigue behavior were investigated. Fatigue behavior of B/SiC-Ti was studied for a variety of loading conditions. Filament spacing type defects resulted in a small degradation in tensile and fatigue properties in B-Al and B/SiC-Ti. An evaluation of the effects of overheating during consolidation of B-Al on tensile and fatigue behavior was used to introduce the concept of defect intensity-product quality-processing cost analysis to establish an acceptable temperature range for diffusion bonding.

REPORT NO: AFML-TR-73-182 AD 767 597
 ACCESS NO: 200,674 September 1973
 TITLE: EVALUATION OF AFC 77 MARTENSITIC
 STAINLESS STEEL FOR AIRFRAME STRUCTURAL
 APPLICATIONS
 AUTHOR(S): R. G. Caton; C. S. Carter
 CONTRACT NO: F33615-71-C-1550
 CONTRACTOR: Boeing Company
 PROJECT MONITOR: K. L. Kojola (AFML/LLP)
 PROJECT NO: 7351
 TASK NO: 735105
 ABSTRACT: The fabrication and properties of two high-strength stainless martensitic steel forgings are described. A high level of fracture roughness was achieved in the AFC 77 forging at a tensile strength level of 235 ksi. Stress corrosion resistance, however, was similar to that of competitive steels. The fracture toughness, stress corrosion, and fatigue properties developed in the AFC 77B forging at a tensile strength of 260 ksi were similar to those of currently used steels. Cracking problems were experienced with both forgings during heat treatment. The tensile strength properties of the AFC 77 forging, with the exception of two test results, met the target of 235 ksi. A high level of fracture toughness was achieved in

ABSTRACT (Cont'd): this alloy with a room temperature K_{Ic} of 110 $\text{ksi}\sqrt{\text{in.}}$ and about 80 $\text{ksi}\sqrt{\text{in.}}$ at -65F. This is comparable to the highest levels which can be achieved with medium alloy steels at similar strength levels and is superior to those of competitive stainless steels. Notch fatigue properties were also superior to those reported for medium alloy steels.

REPORT NO: AFML-TR-73-189
 ACCESS NO: 202,333 December 1973
 TITLE: ASSESSMENT OF ULTRASONIC NDT
 INTERROGATION
 AUTHOR(S): S. I. Fickler
 CONTRACT NO: F33615-73-C-5105
 CONTRACTOR: NEXON, Incorporated
 PROJECT MONITOR: M. J. Buckley (AFML/LLP)
 ABSTRACT: An evaluation was made of the feasibility of detecting and characterizing small flaws of the order of one to one hundred microns in materials by means of ultrasonic interrogation techniques. General principles of measurement theory are applied to this problem which indicate the critical relationship that exists between the wavelength of the interrogating signal and the dimension of the anomaly to be identified. These considerations provide the basis for the inference that the domain of measurement applicable to this problem is related to scattering phenomena. Next, existent empirical data relating to bat echolocation and marine bioacoustics are examined to determine empirical feasibility and assist in formulating an analytic model and associated self consistency requirements for locating and characterizing void microcracks. A model is formulated and its applicability verified. Current experimental capabilities are then reviewed which lead to the conclusion that required experimental techniques are within or, at the worst, very close to the current state-of-the-art for equipment technology.

REPORT NO: AFML-TR-73-192 AD 770 205
 ACCESS NO: 202,050 May 1973
 TITLE: WORKABILITY THEORY OF MATERIALS
 IN PLASTIC DEFORMATION PROCESS
 AUTHOR(S): S. Kobayashi; C. H. Lee; S. I. Oh
 CONTRACT NO: F33615-72-C-1645
 CONTRACTOR: University of California
 PROJECT MONITOR: S. O. Davis (AFML/LL)
 PROJECT NO: 7351
 TASK NO: 735108
 ABSTRACT: This investigation is aimed at establishing a workability criteria in upsetting and rolling with reference to occurrence of free surface cracks. A review of the background on workability is given, indicating the need for methods of analysis which provide the required information on the mechanics in metal-working processes. The development

ABSTRACT (Cont'd): of such a method is described. With this method, the workability criterion of SAE 1041 Steel in upsetting, based on the observed fracture conditions, is described. Although workability in rolling was not examined in this investigation it appears possible by the developed theory to construct a workability criterion also in rolling.

REPORT NO: AFML-TR-73-202 AD 769 919
 ACCESS NO: 201, 736 September 1973
 TITLE: CORRELATION OF PROPERTIES AND
 MICROSTRUCTURE IN WELDED TITANIUM ALLOYS
 AUTHOR(S): K. C. Wu
 CONTRACT NO: F33615-72-C-2015
 CONTRACTOR: Northrop Corporation
 PROJECT MONITOR: R. P. Simpson (AFML/LLM)
 PROJECT NO: 7351
 TASK NO: 735102

ABSTRACT: The purpose of this program was to correlate the metallurgical reactions during welding to the mechanical properties and micro-structures in a Ti-6Al-6V-2Sn weldment. Mechanical properties and microstructures resulting from various welding processes and parameters were studied, and the optimum welding parameters and heat-treatments were determined. The effect of long-term thermal exposure was also evaluated. To study the fusion-zone microstructure resulting from various welding processes (cooling rates) and its mechanical properties, four welding processes, manual gas tungsten-arc welding (GTAW), plasma arc welding (PAW), automatic gas tungsten-arc welding (GTAW), and electron beam welding (EBW), were used. In addition, the automatic GTAW process with dual filler-metal was used to determine the influence of fusion-zone composition on microstructure and mechanical properties.

REPORT NO: AFML-TR-73-203 AD 769 451
 ACCESS NO: 201, 933 August 1973
 TITLE: THE RANK-SCORE-TEST - AN IMPROVEMENT
 OF THE RANK-SUM-TEST
 AUTHOR(S): W. Weibull
 CONTRACT NO: F44620-73-C-0066
 CONTRACTOR: Waloddi Weibull
 PROJECT MONITOR: W. J. Trapp (AFML/LL)
 PROJECT NO: 7351
 TASK NO: 735106
 ABSTRACT: The hypothesis that two random samples are from identically distributed but unknown populations can be tested by use of the rank-sum as the test statistic. It is proposed to substitute for it the rank-score, which, as pointed out, supplies more information about the population of the samples under examination. This new statistic is defined and its main properties are indicated. Tables for its application to pseudo-standardized samples have been established by use of two computer programs,

ABSTRACT (Cont'd): thereby enabling tests of the hypothesis that the samples are from populations with identical distribution function, including its shape parameter, if any, but possibly different scale and location parameters. The practical use of the new test has been demonstrated by numerical examples concerning samples of fatigue test data from a large collection prepared at the Boeing Co.

REPORT NO: AFML-TR-73-223
 ACCESS NO: 202,068 September 1973
 TITLE: HIGH TEMPERATURE TITANIUM COMPOSITES
 AUTHOR(S): W. D. Brentnall; I. J. Toth
 CONTRACT NO: F33615-71-C-1873
 CONTRACTOR: TRW, Incorporated
 PROJECT MONITOR: R. L. Crane (AFML/LLC)
 PROJECT NO: 7351
 TASK NO: 735106
 ABSTRACT: Titanium alloy matrix composites reinforced with silicon carbide and single crystal α Al₂O₃ (sapphire) continuous filaments were investigated. Conventional solid state press diffusion binding fabrication methods were used and a preliminary study to optimize fabrication parameters was made. Property evaluations included room and elevated temperature tensile, creep and stress rupture, thermal exposure, ballistic impact and shear strength tests. Filament distribution had a strong influence on composite properties with the most uniform filament packing corresponding to the highest room temperature and elevated temperature properties. These results indicated therefore that monotape fabrication methods should result in improved properties. However the total primary and secondary fabrication exposures should be reduced if it is desired to extend elevated temperature service life capability of SiC-Ti(6Al-4V).

REPORT NO: AFML-TR-73-224
 ACCESS NO: 201,829 September 1973
 TITLE: PROGRAM TO IMPROVE THE FRACTURE TOUGHNESS AND FATIGUE RESISTANCE OF ALUMINUM SHEET AND PLATE FOR AIRFRAME APPLICATIONS
 AUTHOR(S): M. V. Hyatt
 CONTRACT NO: F33615-72-C-1649
 CONTRACTOR: Boeing Company
 PROJECT MONITOR: D. P. Voss (AFML/LLM)
 ABSTRACT: The effects of thermomechanical treatments on the mechanical, fracture and fatigue properties and microstructure of the high-strength, high-purity 2000- and 7000- series aluminum alloys have been investigated. The thermomechanical treatments involved solution treatment at high temperatures to minimize the amount of soluble intermetallics, quenching, pre-aging various amounts hot or cold rolling 10-40% and final

ABSTRACT (Cont'd): aging to an exfoliation-resistant condition. The pre-age steps involved several degrees of underaging and a few overaged treatments. Mechanical, fracture, smooth and fatigue, fatigue crack growth rate and exfoliation corrosion tests were conducted to evaluate the effects of the various TMTs. For comparison purposes, data were obtained on the commercial alloys 2024-T3, 7075-T6, 7475-T61, 7475-T761. In addition, a few TMTs on the commercial 7475 alloy were evaluated. Property data are contracted.

REPORT NO: AFML-TR-73-226 AD 770 343
 ACCESS NO: 202,071 September 1973
 TITLE: MECHANICAL PROPERTIES AND HIGH-TEMPERATURE STABILITY OF Ti-Mo-Al ALLOYS
 AUTHOR(S): T. Hamajima; M. Hida; S. Weissmann
 CONTRACT NO: F33615-72-C-1566
 CONTRACTOR: Rutgers University
 PROJECT MONITOR: S. Fujishiro (AFML/LLS)
 PROJECT NO: 7353
 TASK NO: 735302
 ABSTRACT: The phase diagram of the isopleth section of the Ti-7 at % Mo-Al system has been improved and expanded to include alloys up to 25 at % aluminum. The mechanical and thermal stability of alloys aged in the two-phase region, B + Ti, Al, and in the three-phase region, B + α + Ti₃Al, were correlated to the microstructures. Considerable increases in high-temperature strength and ductility, as well as high-temperature stability, were achieved in a Ti-7 at % Mo-16 at % Al alloy by step-aging. The values for the yield stress, 0.2 at 300, 450 and 600 C were about 130, 118 and 100 kg mm (180, 160 and k30 ksi), and those for the elongation to fracture were 6%, 8%, and 16% respectively.

REPORT NO: AFML-TR-73-228
 ACCESS NO: 201,781 September 1973
 TITLE: FRETTING RESISTANT COATINGS FOR TITANIUM ALLOYS
 AUTHOR(S): D. J. Padberg
 CONTRACT NO: F33615-72-C-1330
 CONTRACTOR: McDonnell Douglas
 PROJECT MONITOR: W. H. Reimann (AFML/LLM)
 PROJECT NO: 7312
 TASK NO: 731201
 ABSTRACT: This report describes a program undertaken to establish the effect of airframe design parameters and environmental conditions upon the severity of fretting in titanium structures and to determine the ability of selected coatings to prevent fretting induced fatigue failures. The total program was performed in six tasks: 1) establish control data; 2) test the effect of surface finish and dissimilar metal assemblies; 3) double

ABSTRACT (Cont'd): load transfer measurements to identify critical parameters; 4) the effect of selected coatings on the fatigue resistance of Ti-6Al-6V-2Sn; 5) effect of environmental factors tested and it was shown that salt deposits in the faying surfaces led to fretting failures; 6) selected coatings were tested in fretting-fatigue. Shot-peening, anodize with solid lubricant, and epoxy primer alleviated fretting-fatigue under certain conditions.

REPORT NO:	AFML-TR-73-235	AD 769 343
ACCESS NO:	201,935	September 1973
TITLE:	SOLID SOLUTION SOFTENING (RHENIUM DUCTILIZING EFFECT) AND BUBBLE STRENGTHENING IN TUNGSTEN-RHENIUM ALLOYS	
AUTHOR(S):	R. P. Simpson	
CONTRACTOR:	Internal	
PROJECT MONITOR:	R. P. Simpson (AFML/LLM)	
PROJECT NO:	7351	
TASK NO:	735102	
ABSTRACT:	<p>The effect of carbon additions to tungsten and tungsten-rhenium alloy was determined by anelastic relaxation, stress relaxation and mechanical property studies. The solid solubility of carbon is too low to allow a significant effect even at high rhenium concentrations. The thermal component of flow stress was determined in electron beam zone refined single crystal tungsten and tungsten-rhenium alloys by strain rate cycling measurements. Rhenium alone, rather than a combination of rhenium and interstitials, lowers the lattice friction stress and is responsible for the ductilizing effect in tungsten. Bubbles were identified at grain boundaries of recrystallized, doped tungsten and tungsten-rhenium alloys from scanning electron microscopy studies of intergranular fracture surfaces. Auger electron spectroscopy demonstrated that these bubbles are coated with K which is highly localized at grain boundaries. The bubbles raise recrystallization temperature and control grain growth texture and are responsible for the high temperature creep properties of "doped" tungsten and tungsten-rhenium alloys.</p>	

REPORT NO: AFML-TR-73-244 AD 770 216
ACCESS NO: 202,049 September 1973
TITLE: EXPLORATORY DEVELOPMENT ON HYDROGEN
EMBRITTLEMENT OF HIGH-STRENGTH
STEELS DURING MACHINING
AUTHOR(S): K. B. Das
CONTRACT NO: F33615-73-C-5120
CONTRACTOR: Boeing Company
PROJECT MONITOR: P. A. Parrish (AFML/LLP)
PROJECT NO: 7312
TASK NO: 731201
ABSTRACT: This experimental program was undertaken to investigate the possibility of machining fluids being a source of hydrogen for a given high strength aerospace structural alloy. Test specimens made of AISI 4340 high strength steel of known hydrogen concentration were subjected to a specified schedule of gentle and abusive milling and grinding operations using different machining fluids. Following the machining operations the specimens were analyzed for excess hydrogen above the base level with a Boeing developed "Ultrasensitive Hydrogen Analysis System". A total of six different machining fluids with different active chemical components were used in this study. Experimental results are presented with a statistical analysis of the hydrogen concentration data.

REPORT NO: AFML-TR-73-247 Volume I AD 770 350
ACCESS NO: 202,045 September 1973
TITLE: PROGRAM TO IMPROVE THE FRACTURE
TOUGHNESS AND FATIGUE RESISTANCE OF
ALUMINUM SHEET AND PLATE FOR
AIRCRAFT APPLICATIONS
AUTHOR(S): D. S. Thompson; S. A. Levy; G. E. Spangler
CONTRACT NO: F33615-72-C-1202
CONTRACTOR: Reynolds Metals
PROJECT MONITOR: K. L. Kojola (AFML/LLM)
PROJECT NO: 7351
TASK NO: 735105
ABSTRACT: A variety of thermomechanical processing practices have been investigated in 2000 and 7000 series alloys. These have been of the form: solution heat treat, quench, pre-age, work harden and final age. The closest approach to achieving all the 2000 series goals simultaneously was in a heavily worked, naturally aged condition; designated - T3E9. X2048 was solution heat treated, quenched, aged at room temperature, and then cold rolled. In this temper, exfoliation resistance was good at the thinner gages but was not acceptable at .50-inch gage. When X2048 was overaged in order to produce acceptable exfoliation resistance at all gages, toughness no longer met the goals. Overaging time-temperature combinations failed to reveal any that resulted in meeting the goals of exfoliation resistance and toughness simultaneously. The effects of Cu (1.9 and 1.3%)

ABSTRACT (Cont'd): and Mg (2.5 and 1.7%) content of 7000 series alloys were evaluated together with the pre-age and thermomechanical working conditions. It was found that the highest properties were obtained with the lower Cu and Mg contents, with an overaged pre-age followed by a warm rolling operation.

REPORT NO: AFML-TR-73-252 AD 770 950
 ACCESS NO: 202,088 September 1973
 TITLE: THE INFLUENCE OF EXTRUSION-CONSOLIDATION VARIABLES ON THE INTEGRITY AND STRENGTH OF THE PRODUCT FROM PRE-ALLOYED 7075 ALUMINUM POWDER
 AUTHOR(S): F. J. Gurney; D. J. Abson; V. DePierre
 CONTRACT NO: F33615-71-C-1163
 CONTRACTOR: Westinghouse Electric
 PROJECT MONITOR: A. M. Adair (AFML/LLM)
 PROJECT NO: 7351
 TASK NO: 735108
 ABSTRACT: An investigation was made of extrusion-consolidation processing variables for the production of sound product from spherical 7075 Al alloy powder canned in evacuated cylinders with approximately 60% starting powder density. Maximum product integrity and tensile properties were obtained by extrusion of 700F to 800F with 6:1 to 10:1 reduction ratio. At lower reduction ratios the extruded product exhibited gross cracking and was not completely dense. At a reduction ratio of 40:1, the powder product had significantly poorer tensile properties attributable to the formation, during extrusion and heat treatment, of longitudinal cracks at the powder particle boundaries and to the microstructure produced within the particle grains by the thermal-mechanical processing conditions. Recommendations for improving the processing and product characteristics of the metal powder are made.

REPORT NO: AFML-TR-73-268
 ACCESS NO: 201,830 September 1973
 TITLE: STRESS CORROSION CRACKING OF TITANIUM AND TITANIUM BASE ALLOYS IN AQUEOUS AND GASEOUS MEDIA
 AUTHOR(S): F. H. Beck; M. G. Fontana
 CONTRACT NO: F33615-72-C-1917
 CONTRACTOR: Ohio State University
 PROJECT MONITOR: H. B. Kirkpatrick (AFML/LL)
 PROJECT NO: 7312
 ABSTRACT: Oxygen was found to increase significantly the stress corrosion cracking susceptibility of titanium alloys to methanol and bromine environments, and the initial exposure stage is highly sensitive to the presence of moisture which can absorb on the surface and provide a

ABSTRACT (Cont'd): protective film of water. Cracking planes in single crystal specimens were affected by stress level, chemical factors and specimen orientation. Discontinuous crack propagation and discontinuous dislocation pile-ups appear to be closely related and are responsible for "zig-zag" crack propagation. An X-ray microscopy technique, used for in situ observations of crack propagation of 5 mil specimens, was abandoned because of poor resolution. Depth profiles of hydrogen concentration by ion microanalysis were made of cathodically charged commercially pure titanium and titanium alloys and stress was found to be a factor in determining the tendency for absorption of hydrogen. The importance of anodic dissolution in the stress corrosion cracking process is considered and discussed in depth.

REPORT NO: AFML-TR-73-290
ACCESS NO: 202,240 December 1973
TITLE: FAILURE PROCESSES IN METAL
MATRIX COMPOSITES
AUTHOR(S): J. E. Alexander; R. G. Carlson
CONTRACT NO: F33615-72-C-1713
CONTRACTOR: General Electric Company
PROJECT MONITOR: E. Joseph (AFML/LLC)
PROJECT NO: 7351
TASK NO: 735107
ABSTRACT: Boron/Aluminum composites containing 50 v/o of 5.6 diameter B in two composite matrix materials (2024Al and 6061Al) consolidated from commercially available and continuous rolled bonded (CRB) tapes, have been evaluated in tensile, fatigue, compression, shear, torsion, and rupture tests. Failure modes have been delineated and an extensive number of salient observations made. The information contained in this report will advance the state-of-the-art in metal matrix composite, enhance the technology base and aid in future evaluation of failure responses in aluminum composites.

ELECTROMAGNETIC MATERIALS DIVISION (AFML/LP)

REPORT NO: AFML-TR-72-217 AD 768 332
 ACCESS NO: 201,701 May 1973
 TITLE: THE VAPOR PRESSURE AND HEATS OF
 VAPORIZATION OF NICKEL
 AUTHOR(S): E. Rutner; G. L. Haury
 CONTRACTOR: Internal
 PROJECT MONITOR: G. L. Haury (AFML/LP)
 PROJECT NO: 7360
 TASK NO: 736001
 ABSTRACT: A determination was made of the vapor pressure and heat of vaporization of solid nickel between 1233 and 1658°K. Best values of the absolute ionization cross sections to be used in mass spectrometry for Ag, O, O₂, and Ni were deduced from the literature. A statistical treatment of all the available data of the vapor pressure of nickel gave the following "best value" for the heat of vaporization of solid nickel: $(\Delta H_{\text{O}}^{\circ})_{\text{vs}} = 101.45 \pm 0.62$ kcal/mole.

REPORT NO: AFML-TR-72-244
 ACCESS NO: 202,146 May 1973
 TITLE: A UNIQUE METHOD FOR MONITORING CABIN
 AIR POLLUTION FROM ENGINE OIL IN THE
 EB-57D AIRCRAFT
 AUTHOR(S): W. J. Crawford; H. A. Wells
 CONTRACTOR: Internal
 PROJECT MONITOR: W. J. Crawford (AFML/LPA)
 PROJECT NO: 7360
 TASK NO: 736005
 ABSTRACT: A simple reliable method for monitoring engine oil pollution in aircraft atmospheres is presented. The method involves use of a specially designed sampling device and a standard quantitative infrared spectroscopic procedure. The report describes the use of this device to evaluate an air decontamination system on the EB-57D aircraft. A catalytic filter has been recommended for use in the EB-57D aircraft to lower the oil content in the cabin atmosphere.

REPORT NO: AFML-TR-72-246
ACCESS NO: 201,291 November 1972
TITLE: BARIUM SODIUM NIOBATE AS A NONLINEAR
OPTICAL MATERIAL
AUTHOR(S): W. J. Silva; A. Rosengreen
CONTRACT NO: F33615-71-C-1369
CONTRACTOR: Crystal Technology, Inc.
PROJECT MONITOR: V. L. Donlan (AFML/LPL)
PROJECT NO: 7371
ABSTRACT: Growth of barium sodium niobate crystals from
twenty-five different compositions in the single phase, solid solution region
of the ternary phase diagram is described. Correlations between color
center formation, strain, phase-matching temperature and composition are
made. Crystals grown from melts containing less than 48.5 mol percent
niobium pentoxide are colorless. Results of extinction ratio measurements
for crystals of one composition and SHG measurements for crystals of
several compositions are given.

REPORT NO: AFML-TR-73-46 AD 758 806
ACCESS NO: 201,356 March 1973
TITLE: RESEARCH TO INVESTIGATE THE AGING CHAR-
ACTERISTICS OF SAMARIUM COBALT MAGNETS
AUTHOR(S): H. F. Mildrum; K. J. Strnat
CONTRACT NO: F33615-72-C-1795
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: D. Evans (AFML/LPE)
PROJECT NO: 7367
TASK NO: 736703
ABSTRACT: A program of experimental work is outlined which
is aimed at testing the stability of commercially produced, sintered SmCo_5
permanent magnets. The types of environmental exposure tests planned, the
test designed test fixtures, and the testing laboratory in general are described
and depicted. Instrument calibration, specific test procedures, and some
special measurement problems encountered are discussed. Test sample
selection status of magnet procurement, sample allotment to specific tests,
etc., are reported. Some initial results of hysteresis loop and remanence
measurements on as-received samples are presented in tabular and in
graphic form to illustrate the range of properties found in the first batch of
samples received.

REPORT NO: AFML-TR-73-50 AD 760 178
ACCESS NO: 202,159 June 1973
TITLE: TECHNOLOGY DEVELOPMENT FOR TRANSITION
METAL-RARE EARTH HIGH-PERFORMANCE
MAGNETIC MATERIALS

AUTHOR(S): J. J. Becker
CONTRACT NO: F33615-70-C-1626
CONTRACTOR: General Electric Co.
PROJECT MONITOR: J. C. Olson (AFML/LPE)
ABSTRACT: Contributions to the coercive force from expanding domain walls and from interphase boundaries are considered. A phenomenological model for the magnetizing field dependence of the behavior of single particle is described. Theory and experiments relating to coercivity in cobalt-rare earth compounds are reviewed. Coercivity is predominantly limited by the nucleation of reverse domains by defects. Domain-wall pinning also influences coercivity in some cases. In sintered magnets, x-ray lattice parameters, chemical composition, phase identification by metallography, and magnetic properties have been measured by a series of closely spaced compositions. The peak magnetic properties occur when the composition is close to the $\text{Co}_5\text{Sm}-\text{Co}_7\text{Sm}_2$ phase boundary. Changes in lattice parameter with temperature over the range 77° to 300°K are reported.

REPORT NO: AFML-TR-73-52
ACCESS NO: 201,553 April 1973
TITLE: RESEARCH AND DEVELOPMENT ON LASER,
SEMICONDUCTING AND MAGNETIC MATERIALS

AUTHOR(S): P. P. Yaney; J. A. Detrio; J. M. O'Hare;
C. W. Searle; R. L. Jones
CONTRACT NO: F33615-71-C-1121
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: V. L. Donlan (AFML/LPL)
PROJECT NO: 7371
ABSTRACT: A final report on the work accomplished during a two-year program on laser, semiconducting and magnetic materials is presented. High-resolution optical spectroscopy and EPR studies were carried out. Electrical characteristics of the insulating and semiconducting states of the doped CdF_2 system were studied and LED's were constructed using this system. Extensive theoretical and computational studies were carried out of the YAlO_3 and SrF_2 doped materials. Electrical and optical properties of ZnSe doped with Li, Cu, or Na as well as samples implanted with Zn and samples of ZnO hydrothermally grown with Li, CdS, or ZnS were studied. Also, measurements were made on radiation damaged Ge and Si. The intrinsic coercive force in multidomain single crystal (rare earth) Co_5 alloys were studied and a model describing the observed behavior is presented.

REPORT NO: AFML-TR-73-60 AD 760 777
ACCESS NO: 201,463 February 1973
TITLE: MATERIALS PROCESSING OF RARE EARTH
COBALT PERMANENT MAGNETS
AUTHOR(S): P. J. Jorgensen; R. W. Bartlett
CONTRACT NO: F33615-70-C-1624
CONTRACTOR: Stanford Research Institute
PROJECT MONITOR: H. J. Garrett (AFML/LPE)
ABSTRACT: A study of the oxidation kinetics of SmCo_5 involving selective oxidation of samarium was extended from high temperatures to 100°C without a change in the diffusion-controlled rate mechanism. The low temperature oxidation rates are consistent with the amount of oxidation normally observed in SmCo_5 powders, and with the temperature rise expected from oxidation of ground powders. The solubility of oxygen in SmCo_5 at 1130°C in excess of the 800°C solubility was determined to be 3500 ± 500 ppm. The source of oxygen during sintering is the oxide sub-scale. Submicron oxide particles precipitate within the SmCo_5 grains on cooling from the sintering temperature. Oxidation causes depletion of samarium and precipitation of $\text{Sm}_2\text{Co}_{17}$ particles within grains. Both inclusions are postulated to be sources of domain wall nucleation. The oxide inclusions can be removed at 800°C by an aging treatment, that collects the oxide into a few large grains outside the SmCo_5 grains by a solution/re-precipitation mechanism involving grain boundary transport of samarium.

REPORT NO: AFML-TR-73-63 AD 766 759
ACCESS NO: 201,681 March 1973
TITLE: AN IMPROVED CHEMICAL IONIZATION MASS
SPECTROSCOPY SYSTEM
AUTHOR(S): J. H. Futrell
CONTRACT NO: F33615-72-C-1173
CONTRACTOR: University of Utah
PROJECT MONITOR: W. Powell (AFML/LP)
PROJECT NO: 7367
TASK NO: 736702
ABSTRACT: The major thrust of the work reported here has been the development of a sophisticated and versatile medium resolution chemical ionization mass spectrometer. Because of special features of the ion source and optics the sensitivity of this apparatus exceeds by orders of magnitude the capabilities of previous instrumentation. A new ion source and related sample handling modifications based upon the design and testing of this spectrometer has been provided for the DuPont Model 490 mass spectrometer at the Air Force Materials Laboratory. A versatile interface for computer operation of mass spectrometer systems coupled to a PDP 11/20

ABSTRACT (Cont'd): computer has also been designed. Hardware and software developed for this purpose are described. Some preliminary results using an interfaced gas chromatograph/chemical ionization mass spectrometer/computer system are presented.

REPORT NO: AFML-TR-73-80 AD 760 977
 ACCESS NO: 202,298 May 1973
 TITLE: SOLAR ABSORBER COATING STUDY
 AUTHOR(S): R. E. Peterson; J. W. Ramsey
 CONTRACT NO: F33615-72-C-1689
 CONTRACTOR: Honeywell, Inc.
 PROJECT MONITOR: R. M. Van Vliet (AFML/LPE)
 PROJECT NO: 7360
 TASK NO: 736001

ABSTRACT: This study has examined solar absorber coatings intended for use on a solar heat source system to provide thermal energy to drive spaceborne Vuilleumier cycle cryogenic refrigerators. The tests have evaluated potential coating durability for an expected 3 to 5 years in space at an operating temperature of 1600°F. Two coatings, Al203-Mo-Al203 (AMA) and Al203-Pt-Al204 (APA) were tested on four substrates: stainless steel, Inconel, TZM and Cb-1 percent Zr. On stainless steel and Inconel substrates both coatings were found to withstand one hour vacuum bakes up to 1700°F. Auger analysis indicated components of the Inconel of SS had diffused completely throughout the coating at higher temperatures. For both coatings on TZM and Cb-1 percent Zr substrate, breakdown occurred after one hour bakes at 1950°F due to interdiffusion of the coating layers. Further testing was performed on the Cb-1 percent Zr and TZM substrates. Several such samples were given 500-hour bakes at 1700°F.

REPORT NO: AFML-TR-73-82 AD 766 336
 ACCESS NO: 201,588 February 1973
 TITLE: A FLUORINE-19 NMR STUDY OF SOME FLUORO-TITANIUM (IV) COMPLEXES III
 AUTHOR(S): R. S. Borden
 CONTRACT NO: F33615-72-C-1118
 CONTRACTOR: Wittenberg University
 PROJECT MONITOR: D. S. Dyer (AFML/LPA)
 PROJECT NO: 7367
 TASK NO: 736702

ABSTRACT: The stereochemistry of a number of titanium (IV) fluoride complexes has been studied by means of low temperature fluorine-19 NMR. Structural assignments as well as chemical shift and coupling constant data are presented for each observed complex. In the systems involving water, species containing hydroxyl groups could not be detected although hydrolysis was clearly indicated by the formation of a white precipitate.

REPORT NO: AFML-TR-73-112 AD 762 304
ACCESS NO: 201, 556 May 1973
TITLE: RESEARCH AND DEVELOPMENT OF RARE EARTH-
TRANSITION METAL ALLOYS AS PERMANENT-
MAGNET MATERIALS
AUTHOR(S): A. E. Ray; K. J. Strnat
CONTRACT NO: F33615-70-C-1625
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: D. Evans (AFML/LPE)
PROJECT NO: 7371
TASK NO: 737103
ABSTRACT: The results of room temperature saturation mag-
netization and anisotropy measurements made using an oscillating specimen
magnetometer are reported for single crystals. Measured values support
earlier measurements made on packed powders of the same compositions.
The cerium-cobalt alloy system has been re-examined and a revised phase
diagram is proposed. The thermal stability of the RCo₅ phase was investi-
gated in CeCo₅, PrCo₅, and NdCo₅ utilizing metallography, scanning elec-
tron microscopy, electron probe microanalysis, differential thermal analysis
and thermomagnetic analysis. Heat treating alloys for 420 hours at 500°C
resulted in no apparent decomposition of the RCo₅ alloys.

REPORT NO: AFML-TR-73-139 AD 769 447
ACCESS NO: 201, 929 July 1973
TITLE: ELECTRON SPECTRA OF VAPOR OF SOLIDS
AUTHOR(S): G. K. Schweitzer; W. E. Bull; F. A. Grimm
CONTRACT NO: F33615-71-C-1282
CONTRACTOR: University of Tennessee
PROJECT MONITOR: W. L. Baun (AFML/MBM)
PROJECT NO: 7367
ABSTRACT: The field of high temperature photoelectron spec-
troscopy is a very undeveloped area of research. Under the auspices of an
AF research contract we have constructed a specially-designed high-temper-
ature, laser-heated, photoelectron spectrometer. This instrument has been
tested and has been found to function quite effectively up to temperatures of
over 1500°C. The spectra of numerous high-temperature vapors of solid
inorganic compounds have been measured. The information available from
the spectra will provide considerable experimental data and theoretical
configurations, and chemical properties of high-temperature vapor species.

REPORT NO: AFML-TR-73-141 AD 763 710
ACCESS NO: 202,265 December 1972
TITLE: MAGNETIC AND TRANSPORT PROPERTIES OF
DILUTE MAGNETIC ALLOYS
AUTHOR(S): J. W. Loram; A. D. Grassie; G. Williams;
P. Ford; G. Swallow
CONTRACT NO: F61052-68-C-0011
CONTRACTOR: University of Sussex
PROJECT MONITOR: E. Rutner (AFML/LP)
ABSTRACT: Four aspects of the behavior of dilute magnetic
alloys have been studied in detail. These are 1) The intrinsic properties of
isolated impurities in very dilute alloys as a function of temperature and
field; 2) The effect of interactions between impurities on their intrinsic pro-
perties; 3) The nature and properties of the magnetically ordered state in
more concentrated alloys; 4) Deviations from Mattheissen's Rule in the
resistivities of dilute alloys.

REPORT NO: AFML-TR-73-149
ACCESS NO: 202,199 July 1973
TITLE: EXPLORATORY DEVELOPMENT OF
 $Hg_{1-x}Cd_xTe$
AUTHOR(S): E. L. Stelzer; J. Lin; J. L. Schmitt;
M. W. Scott
CONTRACT NO: F33615-72-C-1612
CONTRACTOR: Honeywell, Inc.
PROJECT MONITOR: R. L. Hickmott (AFML/LPE)
PROJECT NO: 7371
TASK NO: 737102
ABSTRACT: The primary objective of this program was to iden-
tify and control the dominant majority and minority defects in the ternary
alloy (Hg, Cd) Te. In this report we show that the carrier concentration
in as-grown n- and p-type material is limited by foreign atoms. The native
crystalline defects, however, dominate the electrical properties of undoped
material quenched or annealed at high temperatures. The trace analysis
results verify the presence of Cu, Ag and Al in $Hg_{1-x}Cd_xTe$. Thus one
or a combination of these elemental impurities could be responsible for
dictating the carrier concentration of the as-grown material.

REPORT NO: AFML-TR-73-167 AD 769 449
 ACCESS NO: 202,299 July 1973
 TITLE: APPLICATION AND DURABILITY OF SOLAR
 ABSORBER COATINGS
 AUTHOR(S): R. E. Peterson; J. W. Ramsey
 CONTRACT NO: F33615-73-C-5074
 CONTRACTOR: Honeywell, Inc.
 PROJECT MONITOR: R. M. Van Vliet (AFML/LPE)
 PROJECT NO: 7360
 TASK NO: 736001
 ABSTRACT: The suitability of solar absorber coatings for use as the thermal power source to drive spaceborne Vuilleumier cycle cryogenic refrigerators has been further evaluated. The coating tested consisted of layers of Al₂O₃-Mo-Al₂O₃ (AMA) in various substrates. The coating was thermally cycled from 1500 to 1600°F about 10,000 times, simulating conditions for three years in orbit. The coating failed on substrates of Cb-1% Zr with a 10,000 Å Mo overcoat, but showed no degradation on TZM substrates. The emittance from 500 -1750°F was measured on AMA-coated TZM and Mo and uncoated TZM and Mo. The emittance for the coated samples rises from 0.07 at 500°F to 0.20 at 1600°F. The measured emittance values for coated specimens were 20% higher than those calculated from room-temperature measurements of the spectral reflectance. An apparatus and technique were developed for uniformly coating spheres. The effectiveness of the sphere coating as a solar absorber was as high as for coatings on flat substrates and the uniformity was better than 3% over the sphere surface.

REPORT NO: AFML-TR-73-219 AD 768 989
 ACCESS NO: 201,783
 TITLE: MAGNETIC STRUCTURE DETERMINATION OF
 RARE EARTH-COBALT-IRON SYSTEMS, BY
 NEUTRON DIFFRACTION
 AUTHOR(S): W. J. James; R. Lemaire
 CONTRACT NO: F33615-71-C-1332
 CONTRACTOR: University of Missouri
 PROJECT MONITOR: R. D. Hutchens (AFML/LP)
 ABSTRACT: Magnetic, x-ray and neutron diffraction studies were made to determine the magnetic and structural effects produced by substitution of Fe for Co in intermetallic compounds of the CaCu₅-type structure with space group P6₃/mmm. Compounds of Th(Co_{1-x}Fe_x)₅ and Y_xLa_{1-x}(Co_yFe_{1-y})_{4.5-5.0} were prepared by various induction methods and then annealed. The samples were characterized by x-ray powder analysis and metallographically. The easy axis of magnetization was determined by x-ray diffraction of powdered specimens oriented in a magnetic field. For all compounds refinement clearly shows that total ordering of the Fe atoms on either of the two sites is excluded. The Curie temperatures of the Th

ABSTRACT (Cont'd): alloys increase with increasing Fe concentration and are sensitive to the nature of the heat treatment. Intrinsic coercivity decreases with increasing Fe content. This is attributed to disordered substitutions of Th by transition metal atoms.

REPORT NO: AFML-TR-73-222 AD 913 512L
 ACCESS NO: 201, 702 September 1973
 TITLE: THERMAL PROCESSING OF LEAD SULFIDE IN
 VACUUM AND INERT GAS ATMOSPHERES
 AUTHOR(S): G. H. Blount; M. K. Preis; R. T. Yamada
 CONTRACT NO: F33615-72-C-1791
 CONTRACTOR: Santa Barbara Research Center
 PROJECT MONITOR: R. L. Hickmott (AFML/LPE)
 PROJECT NO: 7371
 TASK NO: 737102
 ABSTRACT: Vacuum deposited thin film overcoatings impart a number of desirable properties to thin film PbS infrared photodetectors. By optimizing the reflectance characteristics of the overcoatings, analysis has indicated an improvement in responsivity from 6 to 12% for a number of anti-reflection designs. To protect the sensitive film from atmospheric influences and other long term electronic degradation, photodetectors are normally fabricated with a cover slip bonded to the film and substrate with an epoxy adhesive. By first overcoating the PbS thin film detector elements with As_2S_3 , the resultant detector structure was found to have improved features resulting from 1) passivation of the PbS film surface, and 2) alternation of the aging and detector noise behavior.

REPORT NO: AFML-TR-73-238
 ACCESS NO: 202, 160 June 1973
 TITLE: TECHNOLOGY DEVELOPMENT FOR TRANSITION
 METAL-RARE EARTH HIGH PERFORMANCE
 MAGNETIC MATERIALS
 AUTHOR(S): J. J. Becker
 CONTRACT NO: F33615-70-C-1626
 CONTRACTOR: Battelle Memorial Institute
 PROJECT MONITOR: J. C. Olson (AFML/LPE)
 PROJECT NO: 7371
 TASK NO: 737103
 ABSTRACT: The development of the technology for transition metal-rare earth high-performance magnetic materials that has taken place over the three year contract period is described in this report. This work has covered three general areas: the origin of the coercive force in high-anisotropy materials, phase equilibrium and chemistry, and studies of new materials and processing variables. The coercive force of single particles has been shown to be controlled by defects whose nature determines the behavior of magnetization discontinuities. Magnetic domain observations have been used to measure domain wall energies in several cobalt-rare-earths. The domain

ABSTRACT (Cont'd): behavior of sintered magnets has been observed and correlated with their magnetic properties. A comparative study of chemical analytical techniques has been made and the use of x-ray fluorescence developed as a fast and accurate instrumental technique.

REPORT NO: AFML-TR-73-240
ACCESS NO: 202,130 October 1973
TITLE: VAPORIZATION BEHAVIOR OF SILICON NITRIDE
AUTHOR(S): M. Yamawaki; M. Hoch
CONTRACT NO: F33615-69-C-1531
CONTRACTOR: University of Cincinnati
PROJECT MONITOR: P. W. Dimiduk (AFML/LPH)
PROJECT NO: 7360
TASK NO: 736001

ABSTRACT: The vaporization of Si_3N_4 was studied to determine the gaseous products and the composition of the remaining solid phase. The gas phase above Si_3N_4 was found to consist mainly of N_2 , but Si (also at mass 28) was detected. Solid Si_3N_4 cubes of better than 99% theoretical density were heated in a boron nitride Knudsen cell for various lengths of time. The Knudsen cell was in a temperature gradient, the top about 50° cooler than the bottom, so that the free silicon could condense on it. Following heating, the weight loss of the cubes and the silicon collected on the lid was determined, and the silicon nitride to silicon ratio in the solid phase determined. This ratio was also determined using x-ray diffraction techniques. It was found that during heating, after a certain time, the $\text{Si}_3\text{N}_4/\text{Si}$ ratio in the solid did not change, apparently because a constant boiling composition had been reached. An explanation of the experimental data is offered which assumes that at elevated temperatures the Si_3N_4 phase has a wide homogeneity range, and the constant boiling composition could be $\text{Si}_{.52}\text{N}_{.48}$.

REPORT NO: AFML-TR-73-249
ACCESS NO: 202,093 October 1973
TITLE: RESEARCH TO INVESTIGATE THE AGING
CHARACTERISTICS OF SAMARIUM COBALT
MAGNETS

AUTHOR(S): H. F. Mildrum; Dr. K. J. Strnat
CONTRACT NO: F33615-72-C-1795
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: D. Evans (AFML/LPE)
ABSTRACT: The principal objective is to investigate the aging stability of commercially produced sintered SmCo_5 based permanent magnets from two domestic sources. Current results of measurements of certain engineering design parameters are reported, although many tests are still in progress. Investigations were conducted on cylindrical magnet samples having a $B_d/H_d = 1$. These have included: "Natural" air and vacuum aging at room temperature; natural air aging at room temperature after a pre-stabilizing heat treatment; and accelerated thermal air aging at temperatures

ABSTRACT (Cont'd): between 150 and 300 C. Changes in the hysteresis loop shapes and demagnetization curves before and after exposure are also presented and discussed.

REPORT NO: AFML-TR-73-267
 ACCESS NO: 202,266 October 1973
 TITLE: MATERIALS FOR HOLOGRAPHIC OPTICAL ELEMENTS
 AUTHOR(S): D. H. Close; A. Graube
 CONTRACT NO: F33615-73-C-5137
 CONTRACTOR: Hughes Research Labs
 PROJECT MONITOR: Dr. H. M. Rosenberg (AFML/LPH)
 ABSTRACT: An experimental program was conducted to develop a hologram recording material sensitive at 545 nm. suitable for producing high quality holographic optical elements on spherical plastic visor substrates. Emphasis was placed on dye sensitized dichromated gelatin. Two techniques were developed for preparing gelatin films: a casting technique for basic experiments and a dip-coating technique for spherical plastic visors. Basic experiments on dye sensitized dichromated gelatin determined dye absorption and solubility in the presence of dichromate, studied sensitivity as a function of wavelength, and optimized pre-exposure processing and development procedures. Also tested were some nonaqueous photopolymer films; these show a possibility for an alternate to dichromated gelatin, but do not have acceptable resolution or stability in their present form.

REPORT NO: AFML-TR-73-289
 ACCESS NO: 202,270 December 1973
 TITLE: DEVELOP TECHNIQUES FOR THE PRODUCTION OF A RADIALLY-ORIENTED COBALT-RARE-EARTH MAGNETS
 AUTHOR(S): R. L. Horowitz; J. R. Hughes; A. J. Kiesler
 CONTRACT NO: F33615-72-C-1667
 CONTRACTOR: General Electric Company
 PROJECT MONITOR: J. C. Olson (AFML/LPE)
 PROJECT NO: 7371
 ABSTRACT: A number of critical applications exist for Co-rare-earth magnets which embody radial symmetry; hence, radial magnetization is of extreme importance. This work addresses the problem of producing Co_5Sm shapes with radial orientation of the crystallographic "c" axis, or easy direction of magnetization, using processing techniques adaptable to manufacturing. Conclusions reached from this work are radially-oriented Co_5Sm rings.

MANUFACTURING TECHNOLOGY DIVISION (AFML/LT)

REPORT NO: AFML-TR-72-269 AD 909 064L
 ACCESS NO: 69,008 March 1973
 TITLE: MANUFACTURING METHODS FOR HIGH STRENGTH-HIGH MODULUS GLASS FIBER
 AUTHOR(S): W. C. Brady; G. R. Machlan; C. L. McKinnis; T. A. Sullivan; R. L. Tiede; F. M. Veazie
 CONTRACT NO: F33615-71-C-1042
 CONTRACTOR: Owens-Corning
 PROJECT MONITOR: L. Kopell (AFML/LT)
 PROJECT NO: 377-9
 ABSTRACT: A program was undertaken to demonstrate a manufacturing process for glass fibers with reproducible properties of 800×10^3 psi tensile strength, 15×10^6 psi modulus of elasticity, density less than 2.55 gm/cc, and shelf life, fiber diameter, and product uniformity comparable to current production glass fibers. It was demonstrated that a glass fiber can be reproducibly formed in a 204-hole bushing operation with average tensile strength in excess of 650×10^3 psi, a modulus of 14.6×10^6 psi, and a density of 2.525. It was shown that test method determines, in great measure, the value of glass fiber tensile strength.

REPORT NO: AFML-TR-72-287
 ACCESS NO: 68,554 January 1973
 TITLE: SLIDING-SEAL ELECTRON-BEAM WELDING OF AEROSPACE STRUCTURES
 AUTHOR(S): R. H. Witt; J. G. Maciora; H. P. Ellison
 CONTRACT NO: F33615-70-C-1806
 CONTRACTOR: Grumman Aerospace Corporation
 PROJECT MONITOR: F. R. Miller (AFML/LTM)
 PROJECT NO: 828-9
 ABSTRACT: Objectives met during the course of the program were to install and demonstrate the operation of government-owned, sliding-seal electron-beam welding equipment; determine optimum SSEB welding parameters for 2014-T651 aluminum, Ti-6Al-4V titanium and HY-130 steel alloys; determine mechanical properties of SSEB weldments made with optimum parameters; demonstrate the capability of the SSEBW equipment to produce acceptable weldments for aerospace structures; and prepare an SSEBW specification for use by the aerospace industry. Repair welding studies for such defects as lack of fusion, porosity and underfill, and vacuum seal reliability were also completed.

REPORT NO: AFML-TR-73-6
ACCESS NO: 90,554 March 1973
TITLE: PROCESS FOR MANUFACTURING MINIATURE
ALUMINUM FLUERIC INTEGRATED CIRCUITS
(MANUFACTURING METHODS)
AUTHOR(S): R. S. Kiwak; C. J. Ahern; J. H. Tarter
CONTRACT NO: F33615-71-C-1347
CONTRACTOR: Bendix Corporation
PROJECT MONITOR: J. R. Williamson (AFML/LTM)
PROJECT NO: 891-0
ABSTRACT: The purpose of this program was to translate the photoetching and diffusion bonding processes utilized in fabricating stainless steel flueric integrated circuits into suitable techniques for fabricating aluminum fuze components. Several aluminum alloys and tempers have been compared and evaluated for etchability and bondability. Techniques using phosphoric acid for etching 5-mil element profiles in 2-mil-thick 1145 H19 aluminum foil have been developed. A mechanized immersion etcher has been built. Batches of element and circuit laminations held to close tolerances have been produced.

REPORT NO: AFML-TR-73-7
ACCESS NO: 69,605 March 1973
TITLE: LOW COST BEARING RING PRODUCTION
MANUFACTURING METHODS
AUTHOR(S): W. J. Chmura
CONTRACT NO: F33615-71-C-1427
CONTRACTOR: Fafnir Bearing Company
PROJECT MONITOR: R. H. Coe (AFML/LTM)
ABSTRACT: The physical and mechanical properties of plastic and powder metal materials were evaluated, along with their fabrication methods, for the capability to be processed into low cost miniature bearing rings of at least ABEC-3 quality. Based on metrological studies and bearing tests, the optimum method is powder metal (PM) compaction followed by race rolling. Race rolling produces a precision race form while reducing porosity in the critical sub-race region. The most promising material was a water-atomized pre-alloyed powder (1/2 percent Mo, 1/2 percent Mn, bal. Fe) carburized to 0.70 percent C. A production loss of prototype bearings of ABEC-5 quality, had the vibration, torque, and deflection characteristics of wrought AISI 440 C stainless steel bearings. The PM bearings had endurance lives sufficient for most low quality miniature bearing applications. Race rolled ring costs averaged 71 percent of the cost of conventionally produced rings.

AFML/LT

REPORT NO: AFML-TR-73-9
ACCESS NO: 69,989 February 1973
TITLE: PBI MANUFACTURING METHODS FOR
HIGH TENACITY YARNS
AUTHOR(S): A. E. Prince; G. R. Ferment; P. A. Sessa;
J. W. Gilpin
CONTRACT NO: F33615-71-C-1312
CONTRACTOR: Celanese Research Company
PROJECT MONITOR: C. S. Anderson (AFML/LTN)
PROJECT NO: 327-1
ABSTRACT: The purpose of this project was to establish, by pilot plant evaluation, the production methods for producing 100 to 840 denier continuous filament PBI yarns with a minimum tenacity of 6.5 grams per denier. Phase I consisted of the establishment of the required manufacturing methods. Phase II consisted of a final demonstration of the effectiveness of the established process by the preparation of 100 pounds of specification yarns. The establishment of manufacturing methods for production of PBI high tenacity yarns has been completed. Target properties were obtained on a number of variants with an overall increase in filament properties. The spinning optimization work indicated that the jet hole size and spinning take-up speed had an obvious effect on spun properties. No effect on spun or drawn properties resulted from varying the wash temperature, drying temperature, or drying time.

REPORT NO: AFML-TR-73-11
ACCESS NO: 67,445 January 1973
TITLE: MANUFACTURING METHODS FOR FABRICATION
OF MESHLESS STORAGE DISPLAY
AUTHOR(S): C. Stephens; J. Hamacher; P. Robusto
CONTRACT NO: F33615-69-C-1936
CONTRACTOR: Hughes Aircraft
PROJECT MONITOR: H. K. Trinkle (AFML/LT)
PROJECT NO: 604-9
ABSTRACT: The objective of this program is to establish and demonstrate manufacturing processes for the production of high resolution meshless storage display tubes. The program at first developed the remaining components of the device structure and fabricated meshless storage display tubes. The second phase included scaling a meshless storage display and a demonstration of capabilities similar to the prototype model. The third phase included the testing to environmental and life specifications and major equipment and technique improvements. Final phase included complete engineering, testing, establishment of a production line and delivery of 25 full-specification tubes. These were all of the improved design. Brightness levels of up to 10fL and resolution up to 220 lines per inch were obtained with extremely fast write and erase speeds.

AFML/LT

REPORT NO: AFML-TR-73-15 Volume I AD 913 546L
ACCESS NO: 69,789 January 1973
TITLE: MANUFACTURING METHODS FOR HIGH
TEMPERATURE REINFORCED PLASTIC
AIRCRAFT RADOMES
AUTHOR(S): P. W. Harruff
CONTRACT NO: F33615-71-C-1380
CONTRACTOR: Brunswick Corporation
PROJECT MONITOR: S. Litvak (AFML/LTN)
PROJECT NO: 392-0
ABSTRACT: A new high temperature composite system has shown
promise for use in future aircraft radomes. The construction is a sand-
wich configuration with quartz fabric reinforced polyimide skins and dielec-
trically matched syntactic polyimide foam. This program was undertaken to
provide improved processes for manufacturing large radomes. Volume I
covers the unclassified results of materials and process and radome
characterization effort. Environmental exposure including thermal aging
resulted in significant reliability data applicable to radome structures.
This effort adequately demonstrated that large radome structures were
possible at considerable cost savings over previous technology. A photo-
chromic coating method was selected for detecting major defects of the
sandwich constructions. Materials and process specifications were written.

REPORT NO: AFML-TR-73-19
ACCESS NO: 201,410 April 1973
TITLE: A STUDY OF THE EFFECTS OF MANUFACTURING
TECHNOLOGY DIVISION PROGRAM ACCOMPLISH-
MENTS ON MANUFACTURING PROCESSES FOR
AIRCRAFT AND AEROSPACE SYSTEMS
AUTHOR(S): E. G. Smith; R. M. Evans
CONTRACT NO: F33615-72-C-1343
CONTRACTOR: Battelle Memorial Institute
PROJECT MONITOR: G. M. Glenn (AFML/LTM)
ABSTRACT: A total of over 625 projects funded by the Manufac-
turing Technology Division (MTD) were reviewed in this study to determine
the extent to which these projects, collectively and/or individually, have
contributed to advancements in manufacturing processes for aircraft and
aerospace systems. There were numerous projects supported by each branch
of MTD which lead directly to improved manufacturing methods. For ex-
ample, 40 of the projects found direct application in the C5A airframe and 38
projects were directly applied in the manufacture of the corresponding TF39
engines. The MTD projects applied directly to other aircraft systems to
similar extents. Based on numerous contacts made with representatives in
the aerospace industry, it became apparent that the majority of MTD-
supported projects provided manufacturing/engineering data which are prov-
ing useful for arriving at firm decisions in aircraft design.

REPORT NO: AFML-TR-73-22 AD 909 066L
ACCESS NO: 202,200 March 1973
TITLE: MANUFACTURING METHODS FOR POLY-
BENZIMIDAZOLE PROCESS SCALE-UP
AUTHOR(S): G. R. Ferment; A. E. Prince; A. Serwetman;
P. A. Sessa; L. E. Trapasso
CONTRACT NO: F33615-71-C-1702
CONTRACTOR: Celanese Research Company
PROJECT MONITOR: C. S. Anderson (AFML/LTN)
PROJECT NO: 328-1
ABSTRACT: The purpose of this program was to finalize the technology and data required for scaling up the design of the PBI production plant to a one million lbs/yr level capable of making 80% staple and 20% filament yarn. Particular emphasis was placed on demonstrating the scale-up of the single-stage polymerization process and evaluating the fiber-forming potential of single-stage polymer. Spinning productivity was increased 50% by the development of 300 hole spinning techniques. A commercial filament yarn process was defined and demonstrated. A hot air tube drawing process was developed which demonstrated improved process stability and productivity over the conventional hot shoe process. Purification and pollution control systems were designed to satisfy the needs of the one million lbs./year production plant.

REPORT NO: AFML-TR-73-23 AD 910 283L
ACCESS NO: 78,557 February 1973
TITLE: LOW TEMPERATURE SILICON EPITAXIAL
MANUFACTURING PROCESSES
AUTHOR(S): F. A. Padovani; L. D. Dyer; B. W. Battershall;
W. L. Workman
CONTRACT NO: F33615-71-C-1386
CONTRACTOR: Texas Instruments
PROJECT MONITOR: E.H.Tarrants (AFML/LTE)
PROJECT NO: 511-1
ABSTRACT: A low-temperature silicon epitaxial manufacturing process was established. The development of the process included work on the following manufacturing techniques: 1) slice cleaning prior to in situ etching, 2) in situ vapor etching, 3) epitaxial deposition, including deposition on heavily arsenic-doped slices; and 4) deposition in a reactor capable of processing 18 2-inch diameter slices simultaneously.

AFML/LT

REPORT NO: AFML-TR-73-24 AD 909 268L
ACCESS NO: 67,372 February 1973
TITLE: ESTABLISHMENT OF MANUFACTURING TECH-
NIQUES FOR BACK-TENSION DRAWING OF
TITANIUM
AUTHOR(S): J. J. Pickett; P. Loewenstein; T. A. Gorecki
CONTRACT NO: F33615-70-C-1247
CONTRACTOR: Whittaker Corporation
PROJECT MONITOR: T. S. Felker (AFML/LTM)
PROJECT NO: 151-0
ABSTRACT: An economical manufacturing technique for the
drawing of precision complex shapes of Ti-6Al-4V was successfully demon-
strated. In Phase I, the draw-bench was modified to permit shuttle drawing
under back-tension conditions using straight land dies as well as drawing
with convex dies. In Phase II, tensile and bend tests were performed on
samples. In Phase III, the semiautomatic draw die constructed in Phase I
was fully automated and provided with a digital readout. In Phase IV, a
drawing die suitable for the finish drawing of larger shapes having a circum-
scribed circle of up to 4" was designed and built.

REPORT NO: AFML-TR-73-30
ACCESS NO: 200,989 March 1973
TITLE: DIFFUSION BONDED B-AI SHEET AND PLATE
AUTHOR(S): J. F. Dolowy, Jr.
CONTRACT NO: F33615-72-C-1329
CONTRACTOR: Amercon, Incorporated
PROJECT MONITOR: A. Lopez; C. S. Anderson (AFML/LTN)
PROJECT NO: 364-1
ABSTRACT: This program effort has resulted in a number of
process improvements or modifications which have had a positive effect on
product quality, producibility, and/or cost. Improvements in the winding
step, combined with improvements in fiber quality and consistency, have
resulted in a substantial decrease in the time and cost of this step as well
as in a consistently higher quality product. These gains were made through
improvements in fiber guides and spool holders, and in more optimum wrap-
ping speed and fiber drag level. The stopoff materials investigation has
resulted in the identification of several effective parting agents and guidelines
for further improvements. Detailed evaluation of effects of foil cleaning
processes on resultant composite quality have confirmed that simple and in-
expensive solvent cleaning is at least as effective as the more complex and
costly cleaning procedures previously used. Quality control procedures,
including temperature control during pressing, have been shown to be con-
sistently effective in producing quality composite. The positive overall im-
pact of the processing studies on production efficiency and product quality
and cost was shown during the fabrication of a series of demonstration
panels.

REPORT NO: AFML-TR-73-41 AD 909 357L
ACCESS NO: 201,392 April 1973
TITLE: MANUFACTURING METHODS FOR COCURING
ADVANCED COMPOSITE MATERIALS
AUTHOR(S): D. L. Stansbarger
CONTRACT NO: F33615-71-C-1824
CONTRACTOR: Northrop Corporation
PROJECT MONITOR: R. N. Casale (AFML/LTN)
PROJECT NO: 422-I
ABSTRACT: This report presents a detailed description of the Manufacturing Methods for Cocuring Advanced Composite Materials. The program objectives were to establish production cocuring techniques for boron/epoxy and graphite/epoxy advanced composite primary aircraft structural components; determining the dimension, mechanical and physical properties of cocured honeycomb sandwich panels, composite-to-composite panels and composite-to-metal panels; and providing a cost analysis between conventional adhesively bonded components and cocured components. The components selected to demonstrate the structural integrity of cocuring techniques were the F-5A supersonic fighter horizontal stabilizer spar splice and root end assemblies.

REPORT NO: AFML-TR-73-47
ACCESS NO: 69,726 March 1973
TITLE: AUTOMATED SHIELD AND WIRE ASSEMBLY
MANUFACTURING METHODS
AUTHOR(S): R. A. Candello
CONTRACT NO: F33615-71-C-1401
CONTRACTOR: MPB Corporation
PROJECT MONITOR: W. A. Harris (AFML/LTM)
PROJECT NO: 736-0
ABSTRACT: The object of this project was to design and build an automatic machine that will assemble shields and retaining wires into miniature bearings at a rate considerably faster and more economical than the present hand method. The assembly machine has been designed and built with four Stations located around a rotary table. It is automatic using a Pneumatic Logic Control Circuit with 100PSI shop air as the only source of power required. The four Stations perform the function of bearing load, shield insertion, wire insertion and bearing unload. The rotary table carries the bearing between Stations. Various size miniature bearings are handled by the machine by changing modular tooling in the bearing load and unload Stations and changing the other Two complete Stations.

AFML/LT

REPORT NO: AFML-TR-73-48
ACCESS NO: 200,132 March 1973
TITLE: COMBINE THE PRIMARY OUTER BEARING
RING BLANK TURNING OPERATION WITH THE
SECONDARY SHIELD RECESS AND SNAP WIRE
GROOVE TURNING OPERATION
AUTHOR(S): H. Johannesson
CONTRACT NO: F33615-71-C-1555
CONTRACTOR: New Hampshire Ball Bearings, Incorporated
PROJECT MONITOR: W. A. Harris (AFML/LTM)
PROJECT NO: 734-0
ABSTRACT: The project objective was directed toward the
determination of the economical feasibility of machining the shield recess
in the outer ring of a miniature bearing during the primary turning operation.
The operation was performed on a multi-spindle automatic screw machine
instead of the present method of performing the operation on a single spindle
machine as a secondary manufacturing operation performed after a qualify-
ing surface grinding operation. This qualifying operation can now be
eliminated also.

REPORT NO: AFML-TR-73-55
ACCESS NO: 201,464 May 1973
TITLE: FORGING-FUNDAMENTALS AND PRACTICES
AUTHOR(S): J. R. Becker; F. W. Boulger; M. L. Rhoten
CONTRACT NO: F33615-71-C-1565
CONTRACTOR: Battelle
PROJECT MONITOR: N. E. Klarquist (AFML/LTM)
PROJECT NO: 220-1
ABSTRACT: This is a manual on forging materials and practices
which both updates and complements the Air Force Manual on the Fundamen-
tals of Forging Practices. The manual provides design engineers with up-to-
date information about the many aspects of forging including descriptions of
important developments made more recently by industry and/or government.
As a set, the manual describes suitable measures for in-process quality
control and quality assurance, summarizes relationships between forging
practices and important mechanical properties and compares various forging
devices to aid in equipment selection. Attention is also given to describing
practices for relatively new materials and energy forging practices.

REPORT NO: AFML-TR-73-58 AD 909 690L
 ACCESS NO: 78,556 March 1973
 TITLE: PRODUCTION OF SINGLE CRYSTAL
 CADMIUM TELLURIDE
 AUTHOR(S): F. Wald; F. J. Bournassa; R. O. Bell
 CONTRACT NO: F33615-71-C-1209
 CONTRACTOR: Tyco Labs
 PROJECT MONITOR: E. H. Tarrants (AFML/LTE)
 ABSTRACT: This report described the work carried out over a two-year period aimed at establishing manufacturing methods for high quality CdTe. Techniques for the extraction of electro-optical modulator bars from directionally solidified ingots are described. The traveling heater method of crystal growth (THM) and doping control is described, and it is demonstrated that nuclear detectors could be fabricated from this material, thus giving an indication of its quality. Chemical analyses and electrical measurement techniques are also reported.

REPORT NO: AFML-TR-73-61 AD 910 689L
 ACCESS NO: 68,001 April 1973
 TITLE: MANUFACTURING TECHNOLOGY FOR MATERIALS, DESIGNS, AND FABRICATION OF EXTRUSION DIES FOR HOT EXTRUDING OF STEEL AND Ti STRUCTURAL SECTIONS
 AUTHOR(S): F. S. Turner
 CONTRACT NO: F33615-70-C-1375
 CONTRACTOR: Allegheny Ludlum Industries, Incorporated
 PROJECT MONITOR: T. S. Felker (AFML/LTM)
 PROJECT NO: 143-0
 ABSTRACT: A ceramic die when adequately supported has potential for use as dies for hot extruding thin complex steel and titanium structural sections. A Si_3N_4 die was used to extrude three forty-five foot long extrusions of Type 304 stainless steel to a 1/16 inch thick "T" section with a 2 inch long flange and a one inch high stem. Surface quality and dimensional uniformity of the extrusions produced was excellent. A pilot production run of 12 "T" shape dies illustrates that large scale production is feasible and that dies could be produced at a cost attractive to the extrusion industry. Materials included were $\text{Mo}_2\text{C-AlN}$, TaC , TaC-TiB_2 , BeO , Carberlox 20, $\text{ZrB}_2\text{-SiC}$, CrB_2 , Cr_3C_2 , and ZrO_2 reinforced with prestressed tungsten cables, metallized hot work tool steels and BeO reinforced with tantalum filament. $\text{Mo}_2\text{C-AlN}$, Carberlox 20 and TaC-TiB_2 all showed excellent results when evaluated as round hole dies.

REPORT NO: AFML-TR-73-62
ACCESS NO: 200,234 March 1973
TITLE: PROCESS FOR THE MANUFACTURE OF
3,3' DIAMINOBENZIDINE
AUTHOR(S): S. M. Speaker, Jr.; H. J. Burke
CONTRACT NO: F33615-71-C-1568
CONTRACTOR: Upjohn
PROJECT MONITOR: F. E. Arnold (AFML/LTP)
PROJECT NO: 320-1
ABSTRACT: This concludes the program for 3,3'-diaminobenzidine (DAB), a critical component for use in the production of PBI and other high temperature fibers. The basic requirements were that minimal quantities of DAB be produced, after the optimized parameters of chemical, engineering, and material requirements for a fiber grade polymer had been determined. The production runs were necessary to demonstrate product and process reproducibility by the proposed process and provide a reliable basis for the design of a one-million pounds/year plant. The process selected for this program consisted of 1) ammonolysis of dichlorobenzidine under pressure and high temperature in the presence of a Cu catalyst, 2) separation of the crude DAB from the reaction mixture by acid-base procedures, 3) purification of crude DAB by C column treatment followed by crystallization with water and ethylene glycol. A plant was designed for production of DAB. Production of smaller quantities of DAB will remain expensive.

REPORT NO: AFML-TR-73-66
ACCESS NO: 202,201 May 1973
TITLE: ELECTRICAL DISCHARGE MACHINE (EDM)
AUTHOR(S): D. J. Moracz
CONTRACT NO: F33165-71-C-1781
CONTRACTOR: TRW Incorporated
PROJECT MONITOR: E. Wheeler; R. A. Dove (AFML/LTM)
PROJECT NO: 729-9
ABSTRACT: The objectives of this program were to increase the efficiency of the electrical discharge machining process, decrease manufacturing costs, increase reliability and structural integrity of production parts, and extend the utilization of EDM manufacturing processes. Optimization of the EDM parameters in order to obtain the maximum efficiency was accomplished by a study of the parameters using multicariable regression analyses. The effects of other variables have been determined in establishing optimum operating conditions and to permit the broadest application of the process by industry. The cost analysis indicated that the EDM process would save \$2.15/vane for that operation. The midspan element machining was not cost effective when plunge cut by EDM as compared to straddle milling. However, by side cutting using a multiple ram EDM approach and low cost electrode machining techniques a cost savings of \$1.85/blade was estimated.

AFML/LT

REPORT NO: AFML-TR-73-85
ACCESS NO: 69,725 April 1973
TITLE: RACEWAY TRANSVERSE RADIUS MEASUREMENT
MANUFACTURING METHODS
AUTHOR(S): K. M. Gordon
CONTRACT NO: F33615-71-C-1402
CONTRACTOR: MPB Corporation
PROJECT MONITOR: W. A. Harris (AFML/LTM)
ABSTRACT: Project was to establish a rapid and reliable raceway transverse radius measurement method that was both repeatable to limits necessary in typical miniature bearing applications, and which did not damage the raceways being measured. A Surface Measuring Interferometer was used for the measurement of miniature bearing raceway curvatures. The Surface Measuring Interferometer agreed statistically with existing Talyrond and Sheffield gages on radius of curvature measurements. Use of the Interferometer in high volume bearing production should allow better control of miniature bearing raceway geometry, and indirectly reduce manufacturing costs.

REPORT NO: AFML-TR-73-86
ACCESS NO: 200,181 April 1973
TITLE: ULTRASONIC MACHINING
AUTHOR(S): W. Grauer
CONTRACT NO: F33615-71 C-1706
CONTRACTOR: Grumman Aerospace Corporation
PROJECT MONITOR: E. Wheeler (AFML/LTM)
PROJECT NO: 703-1
ABSTRACT: Four Basic composite material sandwich structure configurations were selected in order to evaluate the impact of ultrasonics on the drilling of composites: Boron/Epoxy-Epocast-Boron/Epoxy, Boron/Epoxy-Fiberglass/Epoxy-Boron/Epoxy, Boron/Epoxy-Titanium-Boron/Epoxy, Boron/Epoxy-Epocast-Boron/Aluminum. Both stationary and portable rotary ultrasonic drilling tools were evaluated and compared to conventional drilling tools. The program established cutting tool configurations, ultrasonic operating parameters, coolants, cutting feeds and speeds, equipment requirements and cost comparison data. The integrity of the process was established by standard inspection techniques and by static and fatigue testing. The optimized parameters were demonstrated to be cost-effective on all of the material configurations evaluated.

AFML/LT

REPORT NO: AFML-TR-73-88 AD 910 669L
ACCESS NO: 78,294 May 1973
TITLE: MANUFACTURING METHODS FOR PRODUCTION
OF SINGLE-CRYSTAL MERCURY CADMIUM
TELLURIDE
AUTHOR(S): M. J. Brau
CONTRACT NO: F33615-71-C-1899
CONTRACTOR: Texas Instruments
PROJECT MONITOR: E. HTarrants (AFML/LTE)
ABSTRACT: A manufacturing facility for the production of
mercury cadmium telluride infrared detector material has been established.
The facility and the final production process are discussed in detail. The
type of materials prepared in the Manufacturing Methods facility can be
classified into seven categories. The material exhibits electron mobilities
and carrier concentrations of 150,000 cm²/V-sec and 5×10^{14} /cc respectively.
Bulk lifetimes of 5 microseconds have been observed. Several analytical
tools have been evaluated for the study of Hg_{1-x}Cd_xTe. Electron micro-
probe analysis used in conjunction with radioactive isotope dilution tech-
niques appears to be the best and least expensive method of studying
homogeneity. Ingots of larger diameter have not been successfully pre-
pared by the solid-state recrystallization process. Totally different
techniques may be necessary to prepare these larger ingots in a production
facility.

REPORT NO: AFML-TR-73-89 AD 911 754L
ACCESS NO: 77,601 June 1973
TITLE: MANUFACTURING METHODS FOR PRODUCTION
OF SINGLE CRYSTAL GALLIUM PHOSPHIDE
AUTHOR(S): J. W. Burd
CONTRACT NO: F33615-71-C-1621
CONTRACTOR: Monsanto Research
PROJECT MONITOR: E. Tarrants (AFML/LTE)
ABSTRACT: Production processes have been developed for the
manufacture of single crystal gallium phosphite (GaP) in bulk, vapor phase
epitaxial, and liquid phase epitaxial form. The epitaxial films also proved
satisfactory for the fabrication of high temperature rectifiers for use at
temperatures at least up to 300C. The goal for dislocation density in the
bulk material of less than or equal to 10,000/sq. cm. was approached but
not attained. Significant advancements have been made in the state of the art
of these materials and devices. These advancements are an increase in the
size and rate of production of bulk single crystal GaP; commercial availabili-
ty of undoped, n-type p-type and semi-insulating GaP; and volume production
of bright greenlight-emitting diodes.

REPORT NO: AFML-TR-73-108 AD 912 889L
ACCESS NO: 201,683 June 1973
TITLE: MANUFACTURING METHODS PROGRAM 5W
CW ARGON ION LASER
AUTHOR(S): T. F. Johnston; A. S. Halsted
CONTRACT NO: F33615-70-C-1381
CONTRACTOR: Hughes Aircraft Company
PROJECT MONITOR: J. I. Meulemans (AFML/LTE)
PROJECT NO: 607-9
ABSTRACT: The purpose of this program was to investigate areas of technology which would increase the performance or simplify the manufacture of multiwatt airborne cw argon ion lasers. The 3057H system, consisting of the 3157H laser head and the 3557H laser power supply, were developed as embodiments of the results of the investigations. The results of this program are contained in a three-volume final report. Volume I is a technical report describing the key device technology, design features, test results, and production methods associated with the program. Volume II contains installation, operation and servicing instructions for the system. Volume III contains the documentation necessary for the quality production of the laser system. Some of the areas investigated during the design phases of the program were the characteristics of beryllia segments fabricated by various methods with respect to use for the discharge tube bore, methods of producing a bakeable laser window seal, and the development of tube processing schedules to produce long tube life and the elimination of internal window films.

REPORT NO: AFML-TR-73-109 AD 913 300L
ACCESS NO: 69,542 August 1973
TITLE: MANUFACTURING METHODS FOR THE PRODUCTION OF DISK SHAPES BY CONTOUR ROLLING
AUTHOR(S): D. B. Arnold
CONTRACT NO: F33615-71-C-1428
CONTRACTOR: General Electric Company
PROJECT MONITOR: L. F. Clark (AFML/LTM)
PROJECT NO: 204-1
ABSTRACT: A manufacturing methods program to establish a process for producing control cross rolled disks for machining into jet engine compressor and turbine components is described. A process involving the hot isostatic compaction of argon atomized Rene' 95 powder was found to be acceptable for producing contoured preforms. Hastelloy X cans and inserts were acceptable for rolling the contoured preform and were easily removed after rolling. A greater degree of processing and mechanical property flexibility was found with the powder than with the wrought flat plate. The process established can be used to produce contour cross rolled disks of Rene' 95.

REPORT NO: AFML-TR-73-111
ACCESS NO: 200,272 November 1973
TITLE: MANUFACTURING PROCESS FOR RC NETWORKS
AUTHOR(S): K. P. Bretney; J. V. Vane; W. R. Kritzler;
G. A. Patton; D. F. Yoder
CONTRACT NO: F33615-71-C-1685
CONTRACTOR: General Electric Company
PROJECT MONITOR: T. A. Boynton (AFML/LTE)
PROJECT NO: 0002

ABSTRACT: The final report summarizes the effort to develop an automated high speed manufacturing process for the fabrication of complex microelectronic circuits. The manufacturing methods developed during the project were applied to the design and test of two active RC filter networks. The networks chosen to prove the methods developed during this project were a 10 KHz active bandpass filter and a 3.5 KHz low pass filter with a rejection notch at 4.2 KHz. Subsequent testing of the circuits demonstrated that, with the software control of the laser trim and automatic test developed, all circuits were well within the limits set by the specifications. The pilot production demonstration is also discussed. Recommendations for additional applications are presented.

REPORT NO: AFML-TR-73-120 AD 911 943L
ACCESS NO: 200,685 February 1973
TITLE: LOW-COST TOOLING FOR COMPRESSION
MOLDING OF COMPOSITE MATERIALS
AUTHOR(S): D. B. Rasmussen
CONTRACT NO: F33615-72-C-1428
CONTRACTOR: Goodyear Aerospace
PROJECT MONITOR: P. F. Pirrung (AFML/LTN)
PROJECT NO: 420-1

ABSTRACT: The basic purpose of this program was to reduce the costs associated with the tooling used in compression molding of composite materials by evolving manufacturing methods for three selected materials and concepts. The three low-cost tooling concepts selected for evaluation were 1) ceramic/technical cement molds, 2) nickel vaporform molds with suitable backing, and 3) castable zinc alloy molds (Kirk site). The attributes and characteristics of each tool concept were established in Phase I. Phase II of the program was conducted to determine the advantages and limitations of each tool concept so that these tools can be used, as applicable, with complete manufacturing confidence. Tools were designed and fabricated to produce a common aircraft part - a fuselage-to-wing attachment fitting. Parts were molded of boron, graphite, and glass reinforcements selectively reinforced with epoxy, polyimide, and polyester resins. The parts were evaluated for dimensional characteristics and quality. The tool concepts were cost-characterized by comparison of original costs,

ABSTRACT (Cont'd): reliability, repairability, and longevity. Ceramic tool concept was discontinued.

REPORT NO: AFML-TR-73-122 AD 911 833L
ACCESS NO: 200,684 May 1973
TITLE: DEEP-HARDENABLE TITANIUM ALLOY
AUTHOR(S): L. J. Bartlo
CONTRACT NO: F33615-72-C-1152
CONTRACTOR: RMI Company
PROJECT MONITOR: K.L.Love (AFML/LTP)
PROJECT NO: 124-2

ABSTRACT: The purpose of this program was to make available to the aerospace industry a deep-hardenable titanium alloy with good toughness and ductility for thick-section forgings. The alloy composition is Ti-6Al-2Sn-2Zr-2Mo-2Cr-.25Si (Ti-6-22-22S). Portions of all these products were made available to the aerospace industry for evaluation. The remaining material was evaluated for tensile properties, fracture toughness, crack-growth rate characteristics, aqueous-stress-corrosion resistance, tension-tension fatigue properties, elevated temperature properties, elastic tension and shear moduli and density. The fatigue strength, crack-growth characteristics, and aqueous-stress-corrosion resistance of Ti-6-22-22S are excellent.

REPORT NO: AFML-TR-73-124 AD 766 332
ACCESS NO: 201,590 May 1973
TITLE: MANUFACTURING METHODS FOR MACHINING
PROCESSES FOR HIGH MODULUS COMPOSITE
MATERIALS
AUTHOR(S): F. Hanley; J. T. Hardage
CONTRACT NO: F33615-72-C-1504
CONTRACTOR: General Dynamics/Convair
PROJECT MONITOR: P. F. Pirrung (AFML/LTN)
PROJECT NO: 707-9

ABSTRACT: This is a composite machining handbook for use by engineering and production personnel concerned with fabrication of advanced composite structures. The handbook recommends specific cutting tools and machine tool settings for drilling, reaming, countersinking, milling, routing, and sawing boron-epoxy and boron-epoxy/titanium laminate. Material removal test data and portable equipment data are presented for drilling resin matrix boron composite materials at the assembly level. Portable equipment and diamond drills are evaluated and recommended together with instructions for their operation. Test data and recommendations are presented for drilling metal matrix composite materials. Various fabrication techniques were evaluated to determine feasibility of utilizing boron fibers as cost effective cutting media in core drills.

AFML/LT

REPORT NO: AFML-TR-73-135
ACCESS NO: 90,557 March 1973
TITLE: PRECISION HOLE GENERATION METHODS
VOLUME I - DISCUSSION AND SUMMARY
VOLUME II - APPENDIX
AUTHOR(S): C. M. Fleming
CONTRACT NO: F33615-71-C-1548
CONTRACTOR: McDonnell Douglas
PROJECT MONITOR: C. W. Silha (AFML/LTM)
PROJECT NO: 732-1
ABSTRACT: Hole generation and preparation techniques were established for straight and tapered holes with emphasis on metallurgical integrity, surface quality, dimensional quality and economic processing. Drilling and reaming tool geometries, cutting fluids, speeds, feeds and methods were optimized for both machine shop processing using stationary equipment and assembly line processing using portable equipment. Machine shop hole preparation procedures were evaluated for heat treated 300M steel and for Ti-6Al-4V and Ti-6Al-6V-2Sn Ti alloys in the annealed and heat treated conditions. Assembly line hole preparation procedures were evaluated for the above Ti alloys and for these Ti alloys drilled in combination with 2024-T851 and 7175-T736 Al alloys. Volume II contains detailed data on cutting tool evaluation, coolant evaluation, speed-feed studies, dimensional measurements, fatigue results, tool geometry description and test material analyses and mechanical property data. Discussion of the data and conclusions are in Volume I.

REPORT NO: AFML-TR-73-138 AD 913 547L
ACCESS NO: 201,734 May 1973
TITLE: LASER CUTTING MANUFACTURING METHODS
AUTHOR(S): M. Meyer
CONTRACT NO: F33615-71-C-1949
CONTRACTOR: Grumman Aerospace Corporation
PROJECT MONITOR: J. R. Williamson (AFML/LTM)
PROJECT NO: 731-1
ABSTRACT: The purpose of the program was to establish the laser cutting system as a cost-effective process for cutting and trimming alloys used in high-performance aircraft. The program objectives were to evaluate the laser cutting process with a 250-watt, continuous-mode, carbon dioxide laser on two titanium alloys, four super-alloys and two steels; optimize the laser cutting parameters to produce quality cuts with minimal heat-affected zone, kerf width and striations; establish equipment requirements and criteria for a total laser cutting system for sheet and plate materials; and demonstrate and compare the effectiveness of laser cutting with conventional cutting processes.

AFML/LT

REPORT NO: AFML-TR-73-140 AD 913 744L
ACCESS NO: 201, 780 December 1972
TITLE: IMPROVEMENT OF MANUFACTURING METHODS
FOR THE PRODUCTION OF LOW COST
SILICON CARBIDE FILAMENT
AUTHOR(S): H. DeBolt; V. Krukonis
CONTRACT NO: F33615-72-C-1177
CONTRACTOR: Avco System Division
PROJECT MONITOR: L. L. Kopell (AFML/LTN)
ABSTRACT: A manufacturing process for the production of SiC filament was optimized, and produced material with tensile strength routinely over 450 Ksi and frequently over 500 Ksi; at 1000F the decrease in tensile strength of the SiC produced was less than 15% and the results of a scaled-up production demonstration showed that SiC filament could be produced at costs well below \$200/lb at a production level of 2000 lbs. These results in all cases exceeded the objectives of the program. Filament tensile testing and low strength flaw analysis played an important part in the refinement of the SiC manufacturing process. Pitting of the surface caused by electrode arcing phenomena, nonstoichiometric SiC brought about by variations in gaseous species, and internal stress distributions were determined by electron microscopy and x-ray analytical techniques and these results were iterated during the process establishment.

REPORT NO: AFML-TR-73-159 AD 912 981L
ACCESS NO: 201,694 August 1973
TITLE: MANUFACTURING METHODS FOR RAPIDLY
CURING HIGH-TEMPERATURE COMPOSITES
AUTHOR(S): J. Mahon; S. Richter; J. Kouchinsky
CONTRACT NO: F33615-71-C-1797
CONTRACTOR: Grumman Aerospace Corporation
PROJECT MONITOR: C. Tanis (AFML/LTE)
PROJECT NO: 418-1
ABSTRACT: In Phase I, fabrication parameters were established for proper and adequate control and disposition of evolved volatiles, and application of the required compaction pressures for RF-curing of fiberglass-reinforced epoxy, polyimide and polyimidazoquinazoline matrix composite laminates. The use of RF-energy to cure adhesive joints in fiberglass/epoxy-skinned phenolic and aluminum honey comb sandwich structures, in metal-to-metal overlap joints and in fiberglass/epoxy laminates containing through-the-thickness metallic inserts, and internal and external shims was demonstrated. A capacitive coupling tooling concept was developed and applied to the fabrication of fullscale fiberglass/polymide centerbody fuselage panels and fiberglass/epoxy sandwich construction forward strakes for the F-iii aircraft.

AFML/LT

REPORT NO: AFML-TR-73-161 AD 912 982L
ACCESS NO: 201,696 August 1973
TITLE: IMPROVED ADVANCED COMPOSITE BAG
MOLDING PROCESSES
AUTHOR(S): J. Mahon
CONTRACT NO: F33615-71-C 1705
CONTRACTOR: Grumman Aerospace Corporation
PROJECT MONITOR: C. Tanis (AFML/LTE)
PROJECT NO: 425-1

ABSTRACT: The primary objective of this program was to develop improved bag molding procedures for advanced composites. This goal was realized by the development of an improved process which demonstrated superior cost-effectiveness and reliability compared to conventional bag molding with equivalent structural quality. Cost savings in excess of 30% have already been realized on production primary aircraft structures. The improved bag molding procedure was based on three process innovations: reusable, cast-in-place, silicon rubber vacuum bags with closure techniques suitable for all forms of production molding and bonding tools; inexpensive paper bleeder materials; and optimized bag molding cure cycles for advanced composites.

REPORT NO: AFML-TR-73-165 AD 912 968L
ACCESS NO: 200,419 July 1973
TITLE: MACHINING OF NEW MATERIALS
AUTHOR(S): N. Zlatin; J. D. Christopher; J. T. Cammett
CONTRACT NO: F33615-72-C-1104
CONTRACTOR: Metcut Research Association
PROJECT MONITOR: W. A. Harris (AFML/LTP)
PROJECT NO: 740-2

ABSTRACT: New cutting tool materials suitable for machining aerospace alloys were evaluated. In addition, machinability data which is directly applicable to shop usage was obtained on materials grouped as follows: 1) high strength steels, 2) titanium alloys, 3) nickel base and cobalt base alloys, 4) boron/aluminum composites, 5) graphite/epoxy. The machinability data is listed in Tables of Recommendations. Surface finishes were obtained in turning and end milling and force measurements were made in turning, end milling, drilling, and tapping. Cutter deflections in traverse and longitudinal directions resulting from end milling were also measured. In Phase II a study was conducted to determine the effect of experimental chlorinated and sulfurized cutting fluids on the mechanical properties of 3 aerospace alloys: 1) Ti-6Al-4V, 2) Inconel 718, 3) AISI 4340 Steel. Mechanical properties evaluations included high cycle fatigue at both room and elevated temperatures, fatigue crack propagation at two cyclic frequencies, fracture toughness and stress corrosion surface embrittlement exposures.

AFML/LT

REPORT NO: AFML-TR-73-166
ACCESS NO: 69,614 July 1973
TITLE: FABRICATED TURBINE BLADES WITH THERMAL
FATIGUE RESISTANT EDGES
AUTHOR(S): J. Zelahy
CONTRACT NO: F33615-71-C-1415
CONTRACTOR: General Electric
PROJECT MONITOR: J. K. Elbaum (AFML/LTM)
PROJECT NO: 894-0

ABSTRACT: The purpose of this program was to fabricate, component test and engine test multicomponent turbine blades comprised of a Rene' 80 monocrystalline leading edge and a Rene' 80 multigrained, conventionally cast airfoil and shank. Phase I demonstrated the reliability and reproducibility of the multicomponent blade. Phase II included blade fabrication, component testing, and engine testing. Three fabricated monocrystalline Rene' 80 leading edge blades were successfully engine tested on a TF39 core engine. The effort, although primarily directed toward the TF39 DCIP turbine blade, was sufficiently complete that the process can be readily adapted to other advanced air-cooled turbine blades and vanes.

REPORT NO: AFML-TR-73-176
ACCESS NO: 201,740 September 1973
TITLE: MANUFACTURING METHODS FOR
SELF-SEALING FUEL LINES
AUTHOR(S): J. H. Pousson; E. W. Wiggins
CONTRACT NO: F33615-72-C-1391
CONTRACTOR: McDonnell Douglas
PROJECT MONITOR: C. Tanis (AFML/LTF)
PROJECT NO: 445-2

ABSTRACT: The work relates to the establishment of those manufacturing process parameters to permit the use of the braiding process in manufacturing lightweight reproducible, and economical self-sealing fuel lines for combat aircraft. Tests were conducted to determine the required overbraid on aluminum, stainless steel and titanium fuel lines to eliminate deformation and control petalling which result from an impact with a .50-caliber, armor-piercing projectile. The phase II portion of the program involved establishing the braiding process as a means of applying a cover over the sealant material. Phase III involved demonstrating the manufacturing process. In addition, 25 self-sealing fuel line specimens were manufactured and delivered to the USAF for additional testing.

AFML/LT

REPORT NO: AFML-TR-73-183
ACCESS NO: 202,171 August 1973
TITLE: MANUFACTURING METHODS FOR APPLICATION
OF EROSION-RESISTANT COATINGS TO
COMPRESSOR BLADES
AUTHOR(S): G. F. Wakefield, C. L. Yaws
CONTRACT NO: F33615-72-C-1048
CONTRACTOR: Texas Instruments Incorporated
PROJECT MONITOR: J. R. Williamson (AFML/LTM)
PROJECT NO: 491-1
ABSTRACT: The scale-up to production scope of a laboratory
process was accomplished in this manufacturing methods program for
application of erosion resistant coatings to compressor blades. In phase I,
major technical efforts were expended in system setup of the scale-up
equipment, including engineering design, material procurement fabrication,
and installation of all basic components comprising the system: scale-up
reactor, gas control panel, scrubber, and power supply. In phase II, major
technical efforts were devoted to production system evaluation including
operation of the scale-up system in production mode. Coatings produced
from the scale-up process were characterized in lab analysis activities.
Favorable results for adherence and substrate coverage were found for
coatings of 0.5, 1.0 and 1.5 mil thickness. Coating hardnesses were also
sufficient for good erosion resistance with typical results of 2300-2800
(KHN/25 gr load).

REPORT NO: AFML-TR-73-185 AD 913 596L
ACCESS NO: 200,273 July 1973
TITLE: ESTABLISHMENT OF A MANUFACTURING
PROCESS FOR THE PRODUCTION OF BORON/
EPOXY TAPE
AUTHOR(S): T. Schoenberg; R. Loszewski; E. McQuaid;
R. Stout; G. Van Y
CONTRACT NO: F33615-71-C-1680
CONTRACTOR: AVCO
PROJECT MONITOR: D. F. Starks (AFML/LTN)
PROJECT NO: 285-1
ABSTRACT: This report covers work done to establish an im-
proved manufacturing process for boron/epoxy tape, specifically oriented
towards the production of prepreg tapes for automatic tape laying machines.
The width control and tape placement aspects of the program consisted of
the selection and installation of instrumentation on the existing tape forming
equipment to enable the dimensional tolerances to be maintained during on-
line operation. Specifications were prepared for both the tape making pro-
cess and product requirement for the Conrac machine.

AFML/LT

REPORT NO: AFML-TR-73-198
ACCESS NO: 67,738 July 1973
TITLE: PLANETARY BALL SWAGING OF WELDED
TITANIUM ALLOY TUBING
AUTHOR(S): R. F. Huber; H. F. Sawyer; P. Loewenstein
CONTRACT NO: F33615-70-C-1279
CONTRACTOR: Nuclear Metals
PROJECT MONITOR: T. S. Felker (AFML/LTM)
PROJECT NO: 146-0
ABSTRACT: The objective of this program was to provide economic and versatile methods for the production of titanium alloy tubing for advanced aircraft components such as hydraulic systems. Optimum sequences were established for processing welded tubing of diverse sizes and compositions with the planetary ball swager so that the final welded and worked tubing was at least equivalent in properties and attributes to seamless tubing for aircraft application.

REPORT NO: AFML-TR-73-201 AD 913 470L
ACCESS NO: 78,290 September 1973
TITLE: MANUFACTURING PROCESS FOR ULTRAFINE
AMMONIUM PERCHLORATE (UFAP)
AUTHOR(S): D. A. McBride; D. L. Kennicott
CONTRACT NO: F33615-72-C-1476
CONTRACTOR: Hercules Incorporated
PROJECT MONITOR: C. S. Anderson (AFML/LTN)
ABSTRACT: A program to scale up the Hercules freeze dry process for manufacture of ultrafine ammonium perchlorate was undertaken under contract to AFML. The objective was to establish manufacturing methods for the economical production of UFAP having a weight median diameter ranging from 1.0 to 0.5. The process under evaluation is a crystallization process in which precipitation is achieved by freezing an aqueous ammonium perchlorate solution. Crystal sizes are controlled by limiting the size of the droplet which is frozen and/or by controlling solution super-saturation to achieve the desired crystal nucleation rate. Droplet size control utilizes both atomization and formation of water in oil emulsions. Pilot plant evaluations were conducted.

AFML/LT

REPORT NO: AFML-TR-73-211 AD 769 042
ACCESS NO: 201,791 September 1973
TITLE: DESIGN GUIDE FOR USE OF STRUCTURAL
SHAPES IN AIRCRAFT APPLICATIONS
AUTHOR(S): T. G. Byrer
CONTRACT NO: F33615-71-C-1929
CONTRACTOR: Battelle
PROJECT MONITOR: T. S. Felker (AFML/LTM)
PROJECT NO: 245-1
ABSTRACT: A two-part Design Guide has been compiled to provide technical information and data in the production of structural shapes and tubing for aircraft and aerospace requirements. Part I provides selection criteria for shapes and tubing based on availabilities, and design tolerances, and mechanical and physical properties. Part II discusses manufacturing methods for fabricating structural shapes and tubing, namely extrusion, drawing and form rolling. Also Part II reviews competitive processes for manufacturing structural type components. This Design Guide is intended to assist design engineers in assessing the availability and properties of materials being considered in new or modified aircraft and aerospace systems, and to assist potential manufacturers and suppliers in assessing equipment, tooling and processing requirements for fabricating structural shapes and tubing. Materials for aerospace requirements covered in this document include high-strength aluminum alloys, titanium alloys, steels, superalloys, refractory metals, and beryllium.

REPORT NO: AFML-TR-73-241 AD 914 418L
ACCESS NO: 200,834 October 1973
TITLE: MANUFACTURING PROCESSES FOR ADVANCED
COMPOSITE SUBSTRUCTURAL SHAPES
AUTHOR(S): R. J. Bradley
CONTRACT NO: F33615-72-C-1235
CONTRACTOR: Boeing Company
PROJECT MONITOR: C. P. Logan (AFML/LTN)
PROJECT NO: 435-2
ABSTRACT: The objective of this program was to provide the capability of obtaining advanced composite substructural shapes of significantly reduced cost compared with the present hand layup process and to provide cost data for the pultrusion process that will establish a basis for comparing the cost of substructural shapes using advanced composites with the cost of metallic substructural shapes. The use of the pultrusion process with ceramic forming dies and microwave curing will produce substructural shapes of advanced composite materials that are equivalent to autoclave-cured components in strength and are far less costly. The cost of production quantities of equivalent-stiffness sections of graphite/epoxy and drawformed aluminum are approximately two to one, while an equivalent section in titanium would be three times the cost of the advanced composite section.

AFML/LT

REPORT NO: AFML-TR-73-246
ACCESS NO: 68,420 September 1973
TITLE: MANUFACTURING METHODS OF AN ISOTHERMAL
EXTRUSION PROCESS TO PRODUCE
20-FOOT COMPLEX SECTIONS

AUTHOR(S): P. Loewenstein
CONTRACT NO: F33615-70-C-1545
CONTRACTOR: Nuclear Metals, Incorporated
PROJECT MONITOR: T. S. Felker (AFML/LTM)
PROJECT NO: 146-0

ABSTRACT: A program was performed in which an isothermal extrusion system was designed and constructed. Insulation and heating requirements resulted in the construction of a dual-density foamed silica shell containing resistance wire heaters capable of heating and holding the container at 1800 F. The extrusion ram and dies were also made of cast IN-100 nickel superalloy. The extrusion of Ti-6Al-6V-2Sn under isothermal conditions at 1750 F and a ram speed of 0.01-0.25 inch/minute produced a reduction in extrusion pressure of approximately 50% from that experienced in the extrusion of this alloy under conventional conditions. It was found that the IN-100 ram is subject to creep at a pressure of 70,000 lb/inch² at 1600 F.

REPORT NO: AFML-TR-73-260 Part I
ACCESS NO: 200,235 October 1973
TITLE: MASTER ALLOY B/AL TAPE FOR LOW PRESSURE
CONSOLIDATION PART I TAPE PRODUCTION
AND EVALUATION

AUTHOR(S): R. W. Kebler; R. C. Tucker Jr.
CONTRACT NO: F33615-71-C-1732
CONTRACTOR: Union Carbide
PROJECT MONITOR: C. S. Anderson (AFML/LTN)
PROJECT NO: 90875

ABSTRACT: A facility was designed and built for the production of 20 ft. long by 15 inch wide plasma sprayed aluminum matrix monolayer composite tape. Preliminary process design of equipment for producing 77 ft. long tapes was completed. Rolling facilities and techniques for the production of 3 inch wide by 20 ft. long densified plasma sprayed tapes were established. Two types of monolayer tapes suitable for consolidation at low pressures were produced and evaluated. One tape, 5.6 Boron-Al 1100, was consolidated by surface eutectic bonding. The other was 5.7 B/SiC-6061 Master Alloy tape which depends upon liquid phase formation in the plasma coating at pressing temperature for low pressure consolidation. Cost projections for converting filament into master alloy monolayer tape were \$30 per pound for production at 20,000 lbs/year and \$20/lb. for 1,000,000 lbs/year.

AFML/LT

REPORT NO: AFML-TR-73-260 Part II
ACCESS NO: 202, 251
TITLE: MASTER ALLOY B/AL TAPE FOR LOW PRESSURE
CONSOLIDATION PART II TAPE TESTING
AND EVALUATION
AUTHOR(S): D. C. Ruhmann
CONTRACT NO: F33615-71-C-1732
CONTRACTOR: Union Carbide
PROJECT MONITOR: C. S. Anderson (AFML/LTN)
PROJECT NO: 363-1
ABSTRACT: This report summarizes an evaluation to select the best approach for producing boron and B/SiC aluminum monolayer tapes for low pressure consolidation. Phase II of this evaluation was concerned with an in-depth characterization of Type I tape. The evaluation included tensile property determination at room temperature and 400F, stress rupture and creep tests at 400F, interlaminar shear tests at room temperature, and fatigue tests at room temperature and 400F. The fatigue life of the transverse specimens tested at 400 F was significantly lower than the life observed at room temperature. This observation was in contrast to the longitudinal specimen data which showed no discernible difference in fatigue behavior at elevated and room temperature. Six interlaminar shear tests at room temperature were also conducted.

REPORT NO: AFML-TR-73-262
ACCESS NO: 200, 941
TITLE: ROLL SHAPING OF ADVANCED COMPOSITE
SUBSTRUCTURAL SHAPES
AUTHOR(S): C. L. Johnson; L. C. Sruill
CONTRACT NO: F33615-72-C-2078
CONTRACTOR: General Dynamics
PROJECT MONITOR: C. P. Logan (AFML/LTN)
PROJECT NO: 435-2
ABSTRACT: The research and development activity reported in this volume covers the manufacturing technology developed for roll shaping of advanced composite structural shapes. The objectives of this effort were to develop the methods and techniques for roll shaping composite material into usable structural shapes. The process involves curing of straight structural members, then reshaping them to a prescribed contour by using thermal creep forming methods. Descriptions of the design, tooling, fabrication, development inspection, costs and automation studies are included. Detailed explanations are made of processes and techniques developed during the program.

AFML/LT

REPORT NO: AFML-TR-73-264
ACCESS NO: 202,091
TITLE: NUMERICALLY CONTROLLED
CONTOUR FORMING
AUTHOR(S): G. B. Foster
CONTRACT NO: F33615-70-C-1877
CONTRACTOR: Boeing Company
PROJECT MONITOR: J. R. Williamson (AFML/LTM)
PROJECT NO: 791-0

December 1973

ABSTRACT: The objectives of this program were to develop a numerically controlled section-contouring process and to verify its capability to form uniplanar and multiplanar contours in typical airframe structural shapes. A preliminary design study was accomplished to establish rolling machine capacity, control axis requirements, alternate operational modes, and control system approaches. Facility evaluation and process verification tests established process capability for forming typical fuselage stringer and frame contours in annealed and heat-treated aluminum structural shapes. The quality of aluminum parts produced in each operating mode was equal to or better than normal production requirements. A cost study indicated that a savings of \$1,110,000 could be realized by using the NC contouring process to produce the body stringers for a typical 300-airplane program.

REPORT NO: AFML-TR-73-265
ACCESS NO: 200,693
TITLE: MANUFACTURING METHODS FOR PRODUCTION
PROCESS FOR TITANIUM SHEET WITH
CONTROLLED TEXTURE

November 1973

AUTHOR(S): S. F. Frederick
CONTRACT NO: F33615-71-C-1543
CONTRACTOR: McDonnell Douglas Astronautics Company
PROJECT MONITOR: L. F. Clark (AFML/LTM)
ABSTRACT: This report describes a program to develop processing procedures and associated inspection methods for Ti-6Al-4V sheet with controlled texture. A wide range of rolling variables were examined on both production and laboratory equipment. The development of texture at each stage of processing was followed using kpole figures. Emphasis was given to processing compatible with commercial practice; all key rolling steps were done on production mills. The feasibility of using surface wave velocity measurements as an NDT method for texture assurance was demonstrated. The effect of texture on a variety of mechanical properties at temperatures between -320 and 1,800 F was determined. A transverse basal pole type of texture results from rolling high in the alpha-beta field so that a (001) (110) beta texture is formed and the subsequent beta to alpha transformation favors the transverse basal pole orientation because of anisotropic strain constrictions. Basal textures formed by multidirectional rolling at intermediate temperatures are shown to be the result of multiple slip systems with common (1120) slip vectors.

AFML/LT

REPORT NO: AFML-TR-73-271
ACCESS NO: 68,040 December 1973
TITLE: ADVANCED WROUGHT NICKEL-BASE
ALLOY TURBINE DISK EVALUATION
AUTHOR(S): M. M. Allen
CONTRACT NO: F33615-70-C-1387
CONTRACTOR: Pratt & Whitney Aircraft
PROJECT MONITOR: N. E. Klarquist (AFML/LTM)
ABSTRACT: Pursuant to fulfilling the needs of advanced jet engines, a program consisting of two phases was initiated to determine the feasibility of producing an advanced wrought turbine disk with an approximate 100 F operating temperature advantage over existing Astrology production turbine disks. A microstructural evaluation of the effects of processing and heat treatment was also performed to explain test results and to aid in mechanical property optimization. Further studies were then initiated to optimize powder consolidation and processing techniques. The processing sequence established in the subscale studies was then used to produce full-scale billet stock. This evaluation included microstructural studies to determine its uniformity and cleanliness. Subscale flat pancakes were also made and tested for conformance to mechanical property levels established in the subscale evaluation.

REPORT NO: AFML-TR-73-285
ACCESS NO: 201,118 October 1973
TITLE: BORON/ALUMINUM COMPRESSOR BLADES
AUTHOR(S): C. A. Steinhagen; M. W. Stanley
CONTRACT NO: F33615-71-C-1230
CONTRACTOR: General Electric Company
PROJECT MONITOR: C. S. Anderson (AFML/LTN)
PROJECT NO: 855-1
ABSTRACT: The program objective was the application of advanced metallic composite materials to gas turbine compressor blades. It involved advanced design concepts, process refinement, low cost blade fabrication and blade evaluation. The program was outlined to include qualification of blades in a ground engine test and ultimately in an RF-4 flight test. The ground and flight engine tests goals were not achieved due to failure to pass all starting ingestion tests throughout the flight map in a full-stage whirligig. Constant-chord, constant-pitch J79 size airfoils were fabricated, non-destructively evaluated, and machined into specimens. Selected airfoils were subjected to erosion, corrosion, and subsequent ballistic impact-ing. Resonant frequency testing demonstrated the exceptionally good fatigue behavior of the B/Al airfoils.

AFML/LT

REPORT NO: AFML-TR-73-294
ACCESS NO: 201,823 December 1973
TITLE: MANUFACTURING METHODS FOR
DIRECTIONAL RECRYSTALLIZATION PROCESS
AUTHOR(S): P. G. Bailey; R. E. Kutchera
CONTRACT NO: F33615-72-C-1127
CONTRACTOR: General Electric Company
PROJECT MONITOR: K. L. Love (AFML/LTM)
ABSTRACT: The program has successfully accomplished the original objectives of establishing a directional recrystallization process for Ni20Cr2Th02 superalloy extruded shapes on a production scale for high temperature engine components. The directional recrystallization of extruded Ni20Cr2Th02 shapes improves the high temperature rupture properties of the alloy enabling increased component life and engine performance. A significant contribution of the program has been in establishing extrusion processes which produce material having suitable directional recrystallization response. The alloy powder source used in the program was changed successfully late in Phase I; modifications to the established extrusion process were required. The powder change was necessitated by the original vendor (Fansteel) going out of the dispersion strengthened alloy business.

NONMETALLIC MATERIALS DIVISION (AFML/MB)

REPORT NO: AFML-TR-70-5 Part IV AD 910 321L
 ACCESS NO: 201,461 February 1973
 TITLE: LADDER POLYPHENAZINES AND RELATED POLYMERS
 AUTHOR(S): J. K. Stille; E. F. Johnson; M. Kurihara; S. Norris; J. Wolfe; S. Wratten; M. Winegardner
 CONTRACT NO: F33615-71-C-1139
 CONTRACTOR: University of Iowa
 PROJECT MONITOR: F. L. Hedberg (AFML/MBP)
 ABSTRACT: The synthesis of 4,6-dibenzoyl-1,3-phenylenediamine, a polyanthrazoline forming monomer, from 4,6-dinitroisophthalic acid has been accomplished. Initial attempts to synthesize 3,3'-dibenzoylbenzidine, a polyquinoline forming monomer, have not as yet afforded the desired product. A polyanthrazoline, prepared from 4,6-dibenzoyl-1,3-phenylenediamine and 4,4'-diacetyldiphenyl ether, has been synthesized under several sets of reaction conditions in order to determine the most suitable polymerization conditions. The most favorable conditions consist of polyphosphoric acid without added catalyst of m-cresol with a strong acid.

REPORT NO: AFML-TR-70-69 Part III
 ACCESS NO: 202,194 August 1973
 TITLE: CHEMICAL AND PHYSICAL PROPERTIES OF LUBRICANTS, HYDRAULIC FLUIDS AND RELATED MATERIALS
 AUTHOR(S): A. A. Krawetz; J. Krawetz; G. A. Krawetz
 CONTRACT NO: F33615-69-C-1219
 CONTRACTOR: Phoenix Chemical Lab
 PROJECT MONITOR: C. E. Snyder (AFML/MBT)
 PROJECT NO: 7343
 TASK NO: 734303
 ABSTRACT: A method for the determination of the linear flame propagation rates of lubricants and hydraulic fluids has been developed and applied to a variety of samples. The technique of thermoelectric flame detection has been utilized to determine the minimum hot-flame and pre-flame reaction threshold temperatures of five samples at one atmosphere pressure. A gas-chromatographic procedure utilizing measurement of apparent boiling range has been developed for use as a micromethod for the estimation of the thermal and oxidative stabilities of experimental lubricants and hydraulic fluids have been studied. Special emphasis has been directed toward the investigation of properties relevant to the performance of lubricants and hydraulic fluids under conditions of thermal and oxidative stress.

REPORT NO: AFML-TR-71-2 Part 3
ACCESS NO: 79,103 July 1973
TITLE: POLYMER STRUCTURES AND PROPERTIES
PART III. THERMALLY STABLE POLYMERS
AUTHOR(S): C. G. Berry; E. F. Casassa; D. K. Goebel
CONTRACT NO: F33615-70-C-1058
CONTRACTOR: Carnegie-Mellon University
PROJECT MONITOR: M. T. Gehatia (AFML/MBP)
PROJECT NO: 7342
TASK NO: 734203
ABSTRACT: Rheological properties of concentrated solutions of BBB in methane sulfonic acid and sulfuric acid are affected by intermolecular aggregation. Small amounts of absorbed water in these solutions have a strong effect on rheological properties. Creep and creep recovery data on BBB in methane sulfonic acid are discussed. Light scattering and fluorescence studies on dilute solutions of BBB and BBL provide information on molecular weight, dimensions, and segmental motion in solution. The fluorescence polarization in both cases suggests segmental motion slow compared to the lifetime of the excited state, or transfer of the excitation before emission.

REPORT NO: AFML-TR-71-24 Part II AD 908 923L
ACCESS NO: 201,350 January 1973
TITLE: HIGH TEMPERATURE RESISTANT ELASTOMERS
OF COMPLIANT POLYMERS
AUTHOR(S): R. J. Jones; H. N. Cassey
CONTRACT NO: F33615-71-C-1397
CONTRACTOR: TRW, Incorporated
PROJECT MONITOR: T. L. Graham (AFML/MBE)
PROJECT NO: 7340
TASK NO: 734005
ABSTRACT: This report describes the exploratory development of polyimide elastomeric or compliant polymers suitable for use at elevated temperatures as integral fuel tank sealants. The majority of the effort was devoted to the synthesis of polyimide gumstocks from bis (3,4-dicarboxyphenoxyphenyl) sulfone dianhydride (BSDA), polyaliphatic ether diamines (PED) and aromatic diamines and the preparation and evaluation of vulcanizates based on these materials. Polymers prepared from BSDA, methylene dianiline (MDA) and 1000 molecular weight PED were found to possess the most promising combination of thermo-oxidative stability, elongation to break, fuel stability and adhesion. A curing process was developed for the polyimides that did not compromise initial properties of the linear precursors.

AFML/MB

REPORT NO: AFML-TR-71-24 Part III AD 914 653L
ACCESS NO: 202,044 October 1973
TITLE: HIGH TEMPERATURE RESISTANT ELASTOMERS
OR COMPLIANT POLYMERS

AUTHOR(S): R. L. Jones; H. N. Cassey; C. D. Bertino

CONTRACT NO: F33615-71-C-1397

CONTRACTOR: TRW, Incorporated

PROJECT MONITOR: T. L. Graham (AFML/MBE)

PROJECT NO: 7340

TASK NO: 734005

ABSTRACT: This report describes the exploratory development and testing of polyimide elastomeric or compliant polymers suitable for use at elevated temperature as integral fuel tank sealants. The majority of the effort was devoted to the synthesis, cure and evaluation of polyimide gumstocks from bis (3,4-dicarboxyphenoxyphenyl) sulfone dianhydride (BSDA) and aromatic diamines, polyaliphatic ether diamines (PED), or amino-phenyl terminated perfluoro ether monomers. Polymers prepared from BSDA, methylene dianiline (MDA) and 1000 molecular weight PED and subsequently cured with peroxides in the presence of crosslinking agents were found to possess compliant elongations to break sufficient to perform at temperatures down to $\leq -40^{\circ}\text{F}$ under dynamic loading. Cured sealant candidates containing perfluoro segments were shown to have promise for sealant use at temperatures in the range of 550°F to 600°F .

REPORT NO: AFML-TR-71-59 Part II AD 914 706L
ACCESS NO: 202,046 October 1973
TITLE: ELASTOMERS FOR LIQUID ROCKET
PROPELLANT CONTAINMENT

AUTHOR(S): J. W. Martin; H. E. Green

CONTRACT NO: F33615-71-C-1233

CONTRACTOR: TRW, Incorporated

PROJECT MONITOR: J. K. Sieron (AFML/MBE)

PROJECT NO: 7340

TASK NO: 734005

ABSTRACT: This report covers the second part of a technical effort intended to provide new elastomers for AF positive expulsion and fluid sealing needs. Elastomers were developed for service with hydrazine, dinitrogen tetroxide, aircraft hydraulic fluids and fluorinated oxidizers. The following elastomers were studied: 1. AF-E-332, 2. AF-E-411, 3. AF-E-124D, 4. Carboxynitroso rubber/HYSTL composites, 5. two TRW-developed elastomers. Polymerizations were conducted to prepare a perfluorinated elastomer cured by a covalent mechanism. Tests ranged from simple laboratory screening to complete Design Verification Testing of a full-size AF-E-332 positive expulsion bladder.

AFML/MB

REPORT NO: AFML-TR-71-61 Part III
ACCESS NO: 200,563 June 1973
TITLE: IMPROVED HIGH-TEMPERATURE SOLID
FILM LUBRICANTS
AUTHOR(S): V. Hopkins; R. D. Hubbell; M. T. Lavik
CONTRACT NO: F33615-70-C-1226
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: B. D. McConnell (AFML/MBT)
PROJECT NO: 7343
ABSTRACT: This program is concerned with exploratory development work on new and improved solid lubricant materials and processes for requirements within a wide range of environmental conditions. More than 80 self-lubricating compacts and composites have been prepared utilizing partially carbonized phenolic resins (CPR) as the matrix. A wide range of materials, including sulfides, oxides, nitrides, carbides, fluorides, metals, and glass or graphite fibers have been found to be compatible within the CPR system. A series of friction and wear tests were conducted on polyimide bonded MoS_2 and $(\text{CF}_3)_n$ solid lubricant films using the Falex and dual rub-shoe test devices. Most of the effort in the new applications area has involved coating of test specimens with AFSL-27, AFSL-28, and AFSL-29 for evaluation outside of MRI.

REPORT NO: AFML-TR-71-114 Part III
ACCESS NO: 201,615 June 1973
TITLE: SYNTHESIS OF PERFLUOROALIPHATIC
ETHER MONOMERS
AUTHOR(S): T. Psarras
CONTRACT NO: F33615-70-C-1403
CONTRACTOR: PCR, Incorporated
PROJECT MONITOR: R. C. Evers (AFML/MBP)
ABSTRACT: Difunctional perfluoroetheralkyl monomers derived from hexafluoropropylene oxide and tetrafluoroethylene oxide were prepared. These include diiodides and bis-iminoethers. The photochemical and thermal reaction of tetrafluoroethylene with perfluoroalkyl and perfluoroetheralkyl iodides was investigated and the corresponding diiodides were obtained. The photolysis of perfluoroetheralkyl esters and acyl fluorides derived from hexafluoropropylene oxide was studied. The results are interpreted in terms of two major processes leading to a secondary and a primary radical, respectively.

AFML/MB

REPORT NO: AFML-TR-71-201 Part II
ACCESS NO: 200, 313 July 1973
TITLE: EXPLORATORY DEVELOPMENT OF NEW AND
IMPROVED SELF-SEALING SYSTEMS FOR
AIRCRAFT INTEGRAL FUEL TANKS
AUTHOR(S): R. M. Heitz; F. Hill
CONTRACT NO: F33615-70-C-1426
CONTRACTOR: Northrop Corporation
PROJECT MONITOR: T. L. Graham (AFML/MBE)
PROJECT NO: 7340
TASK NO: 734005
ABSTRACT: Modified self-sealing material systems for protecting C-130 integral fuel tanks from being damaged catastrophically by small-arms projectiles were developed. Results of gunfire tests on a C-130 wing tank section containing the three most promising modified self-sealing materials constructions showed all of them to be 100% reliable in sealing wounds inflicted by .50 caliber AP and 20 mm ball projectiles. Some effort was expended on evaluating the sealing performance of the Buna N foam/polysulfide nylon reinforced self-sealing materials composite at -40°F and, after several hours aging at 350°F, at room temperature. At -40°F the compressed foam sealant was still flexible enough to seal wounds inflicted by .50 caliber AP projectiles. A portion of the effort was devoted to investigations into the hydraulic ram forces created as a projectile assumes various positions in attitude in traversing a fuel filled tank.

REPORT NO: AFML-TR-72-57 Part II
ACCESS NO: 201, 854 June 1973
TITLE: DEVELOPMENT OF HIGH TEMPERATURE
LAMINATING RESINS AND ADHESIVES WHICH
CURE THROUGH ADDITION PART II SUMMARY
REPORT
AUTHOR(S): N. Bilow; R. H. Boschan; A. L. Landis
CONTRACT NO: F33615-71-C-1228
CONTRACTOR: Hughes Aircraft Company
PROJECT MONITOR: T. J. Aponyi (AFML/MBC)
PROJECT NO: 7340
TASK NO: 734003
ABSTRACT: Nitrile- and acetylene-terminated polyimides and polyphenyl ethers were synthesized and evaluated as polymer precursors which would cure through addition. When reacted with terephthalonitrile N, N'-dioxide, chain extension and cure occur. Both laminating resins and adhesives were produced in this manner. Homopolymers of the acetylene-terminated polyimides and copolymers of the nitrile-terminated polyimides yielded high strength, high modulus, low void, glass reinforced laminates. In addition, both classes of materials also provided excellent high strength adhesives for bonding Ti to Ti. Bond strengths in the range of 2500 psi were obtained, even at temperatures as high as 450F.

AFML/MB

REPORT NO: AFML-TR-72-72 Part II AD 912 407L
ACCESS NO: 201,684 July 1973
TITLE: EXPLORATORY DEVELOPMENT ON FORMATION
OF HIGH STRENGTH, HIGH MODULUS BORON
NITRIDE CONTINUOUS FILAMENT YARNS

AUTHOR(S): R. Y. Lin; J. Economy; H. Murty

CONTRACT NO: F33615-72-C-1573

CONTRACTOR: The Carborundum Company

PROJECT MONITOR: S. Schulman (AFML/MB)

PROJECT NO: 7320

TASK NO: 732001

ABSTRACT: This report summarizes the second year's effort on "Exploratory Development on Formation of High Strength, High Modulus Boron Nitride Continuous Filament Yarns." Major efforts were concentrated on developing facilities needed for larger scale production. These included construction of a 1000 tip bushing, installation of continuous nitriding furnace and acquisition of an improved tension device. A large amount of effort was devoted to installing and putting into operation the 1000 tip bushing. The possibility of continuously nitriding the boric oxide filament yarn to a proper degree of nitriding was demonstrated. In addition, the feasibility of producing continuous BN filament with an average tensile strength and modulus of 236×10^3 psi (max. 341×10^3 psi) and 33.8×10^6 psi (max. 44.6×10^6 psi) was also demonstrated. These values represent the highest average tensile strength ever observed for boron nitride fibers.

REPORT NO: AFML-TR-72-92 Part II AD 912 957L
ACCESS NO: 201,705 April 1973
TITLE: HIGH TEMPERATURE ELASTOMER

REINFORCING MATERIALS

AUTHOR(S): E. F. Abrams; R. G. Shaver

CONTRACT NO: F33615-72-C-1538

CONTRACTOR: General Technologies Corporation

PROJECT MONITOR: J. K. Sieron (AFML/MBE)

ABSTRACT: Laboratory investigations were performed to optimize processing parameters and develop magnesium oxide and calcium fluoride fibrous reinforcing materials having optimum strength, density, purity, and geometry for reinforcement of fluoroelastomers. Fiber spinning solutions containing chlorides, sulfates and nitrates were investigated with success in producing magnesium oxide fibers over 25 microns in diameter. MgO and CaF₂ fibers with very small diameters were fabricated by a textile conversion process. A simple technique was developed to produce flat MgO flake reinforcement material. Samples of this MgO flake and MgO CaF₂ fibers in both 8.5 μ and 12 μ diameters were furnished to AFML for evaluation.

AFML/MB

REPORT NO: AFML-TR-72-111 Part II AD 911 510L
ACCESS NO: 200,983 June 1973
TITLE: SYNTHESIS OF THERMALLY STABLE POLYMERS
AUTHOR(S): C. S. Marvel
CONTRACT NO: F33615-71-C-1408
CONTRACTOR: University of Arizona
PROJECT MONITOR: G. A. Loughran (AFML/MBP)
PROJECT NO: 7340
TASK NO: 734004
ABSTRACT: Crosslinking of nitrile substituted polymers with aryl ether, ketone and sulfone units in the backbone has been studied. The best resins seem to have come from simple heating to elevated temperatures. $ZnCl_2$ catalyzes the crosslinking but causes voids and makes the polymer more readily oxidized. Dinitrile oxides add to the nitrile groups but crosslinking is not satisfactory. Work on a variety of organometallic catalysts has not produced one that is useful. More arylene polysulfides with nitrile side groups have been prepared and some seem to crosslink when heated with $ZnCl_2$ which causes them to oxidize more readily. It has been found that polymers with phthalocyanine units for crosslinking are not very oxidatively stable and this approach to crosslinking resins has been abandoned.

REPORT NO: AFML-TR-72-112
ACCESS NO: 202,097 March 1973
TITLE: MESOPHASE GRAPHITE
AUTHOR(S): M. P. Whittaker; H. P. Gilliam
CONTRACT NO: F33615-71-C-1396
CONTRACTOR: Great Lakes Research Corporation
PROJECT MONITOR: J. D. Latva (AFML/MBC)
PROJECT NO: 7350
TASK NO: 735002
ABSTRACT: This report contains results and discussions related to the investigation of the materials and process parameters associated with the development of the mesophase-graphite process. Three starting materials were investigated as precursors for preparing mesophase graphite. The conditions for converting these precursors to mesophase and subsequent processing parameters are discussed. Graphites produced from each of these materials were characterized as to strength, density, and coefficient of thermal expansion. Additional work with two of the three precursors was conducted in an effort to determine the feasibility of molding mesophase to shape and using mesophase as a matrix for carbon/graphite fibers.

AFML/MB

REPORT NO: AFML-TR-72-122 AD 915 599L
ACCESS NO: 202,137 September 1973
TITLE: DYNAMIC AND STATIC EVALUATION OF
EXPERIMENTAL INTEGRAL FUEL TANK SEAL
MATERIALS

AUTHOR(S): G. H. Synder; C. A. Schultz
CONTRACT NO: F33615-70-C-1422
CONTRACTOR: Dow Corning
PROJECT MONITOR: W. B. Anspach (AFML/MBE)
PROJECT NO: 7340
TASK NO: 734005

ABSTRACT: A dynamic test apparatus has been designed and fabricated for the purpose of testing experimental aircraft integral fuel tank sealants. The apparatus is capable of closely simulating the conditions encountered by a sealant during a typical aircraft flight. In addition, the apparatus has the flexibility of simulating a virtually unlimited number of stress, temperature, fuel, and pressure conditions, and will automatically repeat the desired test cycle until sealant failure occurs. High temperature aging in JP-7 fuel vapor was performed on Dow Corning 77-028, 77-085, 95-526, 77-108, 3M Polyester, a fiber reinforced polyester, and a Viton sealant formulated by the AFML, and physical properties were determined on the aged specimens both at room temperature and selected high temperatures representative of possible aircraft conditions.

REPORT NO: AFML-TR-72-142 Part II AD 912 397L
ACCESS NO: 201,593 July 1973
TITLE: HIGH TEMPERATURE THERMALLY STABLE
GREASES

AUTHOR(S): A. M. Dobry; D. J. Lindley; R. N. Nipe; A. Zletz
CONTRACT NO: F33615-71-C-1439
CONTRACTOR: Amoco Oil Company
PROJECT MONITOR: J. B. Christian (AFML/MBT)
PROJECT NO: 7343
TASK NO: 734301

ABSTRACT: Amide-imide resins used as thickeners have given very good lives in bearings but coarseness made starting difficult. Surprisingly, particle reduction of the resins by different methods result in greases with poorer bearing lives. Particle length - to - width ratio may be a factor but is not controlling. Greases from Krytox 143 AD thickened with several experimental amide resins give very good lives to 550 F. Greases MCG-68-48 and Krytox 240 AC successfully completed over 300 cycles of 1-hr. on and 2-hrs. off at 400 F 5000 rpm, and 20 lb. radial load and 5 lb. thrust load. Several greases were examined for compatibility with hydraulic fluid by Federal Test Method 5415.1. Thickener has an important effect on resistance to attack by the fluid. Greases from Krytox fluid are resistant to hydraulic fluid up to 212°F for at least 700 hours.

AFML/MB

REPORT NO: AFML-TR-72-184
ACCESS NO: 201,376 February 1973
TITLE: SYNTHESIS AND REACTIONS OF PERFLUORO-
ALIPHATIC GRIGNARD COMPOUNDS
AUTHOR(S): C. Tamborski; D. D. Denson; D. F. Smith
CONTRACTOR: Internal
PROJECT MONITOR: C. Tamborski (AFML/MBP)
PROJECT NO: 7340
ABSTRACT: Perfluoroaliphatic mono- and di-Grignard reagents

have been conveniently synthesized through the metal-halogen exchange reaction. Excellent yields (90-100%) of the mono- or di-Grignard reagent have been obtained by this method. The selection of the proper reaction conditions, e. g., solvent, temperature, and reaction time, is extremely important in the derivation of the various perfluoro-aliphatic Grignard reagents. Although reaction products have been obtained in all instances, the optimum experimental reaction conditions have not been determined as yet.

REPORT NO: AFML-TR-72-191 Part II AD 913 433L
ACCESS NO: 78,289 July 1973
TITLE: MATERIALS AND APPROACHES FOR IMPROVED
CORROSION INHIBITION COATINGS
AUTHOR(S): G. L. Hollec; F. H. Cochs; D. R. Cogley;
I. W. Frutkoff
CONTRACT NO: F33615-72-C-1562
CONTRACTOR: Tyco Labs
PROJECT MONITOR: D. E. Prince (AFML/MBE)
PROJECT NO: 7340
TASK NO: 734007
ABSTRACT: The purpose of this program was to develop new materials and approaches for improved stress corrosion inhibitive coatings for critical stress corrosion prone components of current and future aircraft and missile systems. An improved coating should be self-healing, a multiple-layer coating process has been used. The key element has been the development of a tenacious, adherent anodized layer that is a far more effective base layer than those currently used. The new coating layer is produced by an anodization carried out in low melting point eutectic nitrate mixture. Direct comparison tests of MIL-Spec painted and scratched samples have demonstrated that the new coating is more than four times more effective in inhibiting stress corrosion than previous MIL-Spec coating processes.

REPORT NO: AFML-TR-72-210 AD 766 327
ACCESS NO: 201,596 November 1972
TITLE: FORMATION OF VERY HIGH MODULUS GRAPHITE
FIBERS FROM A COMMERCIAL
POLYACRYLONITRILE YARN

AUTHOR(S): H. M. Ezekiel
CONTRACTOR: Internal
PROJECT MONITOR: H. M. Ezekiel (AFML/MBC)
PROJECT NO: 7320
TASK NO: 732001

ABSTRACT: A commercial yarn containing at least 99.5% acrylonitrile moieties was stabilized and then directly graphitized. Experimental parameters included preparation of yarn with and without size, variations in yarn twist, stabilization conditions, graphitization atmosphere flow rates and directions, temperature, tension, and exposure time. A substantial number of experiments gave graphite fibers with higher tensile strengths and moduli of elasticity than those obtained from any other polyacrylonitrile yarns under similar conditions. A critical step in use of the yarn was the complete removal of spinning size prior to the stabilization oxidation treatment. More than 20 of the samples had tensile strengths between 300,000 and 374,000 psi.

REPORT NO: AFML-TR-72-220 Part I AD 909 372L
ACCESS NO: 201,391 February 1973
TITLE: SYNTHESIS OF AROMATIC AND HETEROCYCLIC
PERI ACIDS. PART I. BIQUINOLINE AND
PHTHALAZINE PERI ACIDS

AUTHOR(S): M. K. O'Rell
CONTRACT NO: F33615-71-C-1545
CONTRACTOR: TRW, Incorporated
PROJECT MONITOR: F. E. Arnold (AFML/MBP)
PROJECT NO: 7342
TASK NO: 734201

ABSTRACT: This final technical report describes the investigation of new synthesis routes for the preparation of tetracarboxylic acid monomers in which the four carboxy groups are paired as two sets of peri oriented groups. A synthesis route was developed for the preparation of 4,4', 5,5'-tetracarboxy-8,8'-biquinoline, a heterocyclic peri acid. Considerable effort was also directed toward synthesis of 1, 4, 5, 8-tetracarboxy-phthalazine. The product obtained in this work was a dicarboxylic acid rather than the desired tetracarboxylic acid.

AFML/MB

REPORT NO: AFML-TR-72-220 Part II AD 914 658L
ACCESS NO: 202, 047 November 1973
TITLE: SYNTHESIS OF AROMATIC AND HETEROCYCLIC
PERI ACIDS PART II. BIQUINOLINE, PHTHALA-
ZINE AND NAPHTHOXYPHENYL SULFONE PERI
AICDS
AUTHOR(S): M. K. O'Rell
CONTRACT NO: F33615-71-C-1545
CONTRACTOR: TRW, Incorporated
PROJECT MONITOR: F. E. Arnold (AFML/MBP)
PROJECT NO: 7342
TASK NO: 734201
ABSTRACT: This report describes the investigation of new syn-
thesis routes for the preparation of a specific group of tetracarboxylic acids
known as peri acids. The majority of the experimental effort was devoted to
the development of novel approaches for the introduction of carboxy groups
into various ring structures. Synthesis routes were investigated for the
preparation of three novel peri acids. Samples of 4, 4', 5, 5'-tetracarboxy-
8, 8'-biquinoline dianhydride were prepared and submitted to Air Force
Materials Laboratory. Several unsuccessful attempts were made to prepare
1, 4, 5, 8-tetracarboxyphthalazine. A synthesis route to bis [4-(4, 5-dicarboxy-
naphthoxy)phenyl] sulfone was also demonstrated.

REPORT NO: AFML-TR-72-229 Part II
ACCESS NO: 202, 297 August 1973
TITLE: DEVELOPMENT OF HIGH TEMPERATURE
FUNCTIONAL FLUIDS
AUTHOR(S): R. Anderson; T. Psarras
CONTRACT NO: F33615-71-C-1406
CONTRACTOR: PCR, Incorporated
PROJECT MONITOR: C. E. Snyder (AFML/MBT)
PROJECT NO: 7340
TASK NO: 734008
ABSTRACT: A series of bis-triazines with perfluoropolyalkylether
substituents and connected group derived from tetrafluoroethylene oxide (FEO)
and/or hexafluoropropylene oxide (HFPO) was prepared. Bis-triazines with
TFEO-derived substituents and connecting group derived from either oxalyl
fluoride (OXF) and HFPO or hexafluoroglutaryl fluoride (HFGF) and TFEO
exhibit excellent low temperature properties and improved viscosities and
ASTM slope. The addition of HFPO to preformed TFEO-oligomers and the
addition of TFEO to preformed HFPO-OLIGOMERS was investigated. The
addition of TFEO to OXF and to HFGF is also discussed.

AFML/MB

REPORT NO: AFML-TR-72-239 AD 913 265L
ACCESS NO: 78,287 May 1973
TITLE: SYNTHESIS OF NITRILE OXIDE CURING AGENTS
FOR PERFLUORALKYL s-TRIAZINE ELASTOMERS
AUTHOR(S): R. W. LaRochelle
CONTRACTOR: Internal
PROJECT MONITOR: R. W. LaRochelle (AFML/MBE)
PROJECT NO: 7340
TASK NO: 734005
ABSTRACT: An improved crosslinking system using a highly purified terephthalonitrile oxide as curing agent for nitrile pendant perfluoralkyl s-triazine elastomers has been synthesized which allows the preparation of unscorched, uniform composition vulcanizates for use as high temperature, fluid resistant seals and sealants for advanced aircraft systems. The synthesis of the nitrile oxide, the elastomer formulations and physical properties of the vulcanizates are presented. The isolation of pure terephthalonitrile oxide has been achieved by the use of pure synthetic intermediates and the careful synthesis and handling of the sensitive nitrile oxide. The triazines cured with the materials evidence little or no scorching.

REPORT NO: AFML-TR-72-247 AD 762 544
ACCESS NO: 201,533 April 1973
TITLE: DEVELOPMENT OF REFLECTIVE MATERIALS
FOR FIRE FIGHTER'S BOOTS
AUTHOR(S): R. M. Stanton
CONTRACTOR: Internal
PROJECT MONITOR: R. M. Stanton (AFML/MBC)
PROJECT NO: 7320
TASK NO: 732002
ABSTRACT: It has been demonstrated that a neoprene binder used in Air Force fire fighter's boots is a hazardous component acting as an efficient absorber of radiant energy emitted from a JP-4 fire. Protective properties of the neoprene is further reduced by the use of carbon black filler which adds to the absorbancy. Simply changing the filler to a more reflective material is not sufficient to overcome the overriding effect of the neoprene binder. Use of fluorocarbon binder materials partially transparent to infrared energy emitted from the JP-4 fire, in conjunction with known reflectors in the 0.6 to 6.0 micron wave length range, provide improved heat block capability. This process warrants further optimization. Because of the apparent high cost of the Viton (vinylidene fluoride/perfluoropropylene copolymer) binders examined in this program an investigation should be conducted to arrive at less expensive, yet still effective binder materials.

AFML/MB

REPORT NO: AFML-TR-72-250 Part I AD 910 027L
ACCESS NO: 201,382 April 1973
TITLE: MULTIDIRECTIONAL REINFORCED CARBON-
CARBON COMPOSITES FOR RE-ENTRY VEHICLE
APPLICATIONS PART I. WEAVE FABRICATION,
MATRIX PROCESSING STUDIES AND COMPOSITE
CHARACTERIZATION

AUTHOR(S): E. R. Stover
CONTRACT NO: F33615-71-C-1436
CONTRACTOR: General Electric Company
PROJECT MONITOR: J. D. Latva (AFML/MBC)
PROJECT NO: 7350
TASK NO: 735002
ABSTRACT: Fine-textured 3-dimensional reinforced C-C com-
posites having three basic types of multi-directional reinforcement geome-
tries have been explored: (1) High-Axial 3-D intended for plug nose tips,
(2) 7-D Cubic which provides off-axis and shear strengthening for shell de-
signs, and (3) 4-D (Omniweave) which was of interest primarily for heat-
shields. Characteristics of the reinforcements have been evaluated by
selective-orientation radiography, which reveals any missing yarns in the
weave. Processing by CVD infiltration, synthetic resin impregnation, and
high-pressure impregnation-bake with coal tar pitch plus graphitization
("PIC+G") is described. Tensile, shear and thermal expansion tests in
both high-axial ("Z") and lateral ("X" or "Y") directions have shown effects
of processing method and final density of 3-D composites. Billets of 3-D
and 7-D materials submitted to a C-C nose tip material assessment program
are described.

REPORT NO: AFML-TR-72-253 AD 911 304L
ACCESS NO: 201,549 March 1973
TITLE: THE PROTECTIVE CHARACTERISTICS OF PBI
AND NOMEK COVERALLS IN JP-4 FUEL FIRES

AUTHOR(S): R. M. Stanton; S. Schulman; J. H. Ross
CONTRACTOR: Internal
PROJECT MONITOR: S. Schulman (AFML/MBC)
PROJECT NO: 7320
TASK NO: 732002
ABSTRACT: Air Force Flight suits made from PBI and Nomex
fabrics were exposed to JP-4 liquid fuel fires to evaluate the thermal protec-
tion qualities offered to flight personnel. The two fabrics were compared on
the basis of flammability, mechanical, and comfort characteristics. Thermal
protection provided by the two materials was based on the mean difference in
per cent body area damaged for sixty flight suits when exposed to a JP-4 fuel
fire. PBI allowed twenty-one point five percent less damage when compared to
Nomex. PBI fabric in addition to providing thermal protection, has been
proven in a full scale wear test to be the most comfortable flight suit fabric
tested by the Air Force Operational Commands.

REPORT NO: AFML-TR-72-254
ACCESS NO: 201,563 March 1973
TITLE: CHARACTERIZATION OF THE ABRASION
RESISTANCE OF PBI AND NOMEX YARNS AND
FABRICS
AUTHOR(S): J. H. Ross
CONTRACTOR: Internal
PROJECT MONITOR: J. H. Ross (AFML/MBC)
PROJECT NO: 7320
TASK NO: 732002
ABSTRACT: PBI and Nomex yarns and fabrics were analyzed for their abrasion characteristics. Dyed and undyed fabrics were evaluated with emphasis on the PBI fabrics. With respect to the PBI and Nomex fabrics; yarn size, ply, ends and picks/inch, and weave affect the abrasion resistance of the fabrics to a greater degree than yarn modulus. Undyed PBI fabric woven of 2 ply yarns had superior abrasion resistance to PBI and Nomex fabrics woven from single yarns. Dyed PBI fabrics which have been chemically treated to achieve thermal stabilization have better abrasion resistance than undyed, unstabilized PBI and commercially available solution dyed Nomex.

REPORT NO: AFML-TR-72-262 AD 764 720
ACCESS NO: 201,793 March 1973
TITLE: STUDIES OF THE BREAKDOWN MECHANISM OF
POLYMERS. VIII. THE THERMAL DECOMPO-
SITION OF A POLY TETRAAZOLATE, TRIAZOLE,
OXATHIAHYDRAZIDE, THIADIAZOLE AND
THIAZOLE
AUTHOR(S): G. F. L. Ehlers; K. R. Fisch; W. R. Powell
CONTRACTOR: Internal
PROJECT MONITOR: G. F. L. Ehlers (AFML/MBP)
PROJECT NO: 7340
TASK NO: 734007
ABSTRACT: A poly(phenylene)imino tetraazolate, and a poly N-phenyltriazole, a polyoxathiahydrazone, a polythiadiazole, and a polydi-thiazole were subjected to decomposition in vacuum at temperatures up to 620°C, and the decomposition mechanisms postulated on the basis of the mass spectroscopic data of the volatiles and the mass spectral, infrared, and elemental analysis of condensibles and residues. A summary of the proposed mechanisms is given in Section IV.

AFML/MB

REPORT NO: AFML-TR-72-265 AD 912 165L
ACCESS NO: 201,592 March 1973
TITLE: SYNTHESIS OF BENZIMIDAZOBENZOPHENANTHROLINE DIBENZOFURAN LADDER POLYMER
AUTHOR(S): A. J. Sicree; F. E. Arnold; R. L. Van Deusen
CONTRACTOR: Internal
PROJECT MONITOR: R. L. Van Deusen (AFML/MBP)
PROJECT NO: 7340
TASK NO: 734004
ABSTRACT: A new aromatic heterocyclic ladder polymer has been prepared by the polycondensation of 2,3,7,8-tetraaminodibenzofuran with 1,4,5,8-naphthalene tetracarboxylic acid or from the acid dianhydride. The ladder polymer, with intrinsic viscosities ranging from 1 to 2 dl/g, exhibited thermal stabilities near 650°C under nitrogen and near 550°C in air.

REPORT NO: AFML-TR-72-266 AD 912 288L
ACCESS NO: 201,599 February 1973
TITLE: BENZIMIDAZOBENZOPHENANTHROLINE POLYMERS DERIVED FROM PHENYLATED QUINOXALINE TETRAAMINES
AUTHOR(S): RF Kovar; F. E. Arnold
CONTRACTOR: Internal
PROJECT MONITOR: F. E. Arnold (AFML/MBP)
PROJECT NO: 7340
TASK NO: 734004
ABSTRACT: New phenylated quinoxaline tetraamines have been prepared and polarized with 1,4,5,8-naphthalene tetracarboxylic acid. The resulting BB-type polymers with pendant phenyl groups along the polymer backbone are soluble in m-cresol. The polymers with inherent viscosities ranging from 0.3 to 0.6 dl/gm in sulfuric acid exhibited thermal stabilities near 500°C under nitrogen and near 400°C in air.

REPORT NO: AFML-TR-72-267
ACCESS NO: 201,608
TITLE: INVESTIGATIONS OF POLYBENZIMIDAZOLE
SYNTHESIS

June 1973

AUTHOR(S): F. L. Hedberg
CONTRACTOR: Internal
PROJECT MONITOR: F. E. Arnold (AFML/MBP)
PROJECT NO: 7340
TASK NO: 734004

ABSTRACT: To investigate the suitability of a sample of 3,3', 4,4'-tetraaminodiphenyl, from a new commercial source, for the synthesis of polybenzimidazoles (PBI), two standard procedures were used. 1. Melt phase reaction with diphenyl isophthalate, afforded a hydrated product of low viscosity. 2. Reaction with isophthalaldehyde bis (bisulfite adduct), in refluxing N, N-dimethylacetamide, did not give meaningful results because of difficulties in purifying the bis (bisulfite adduct). A new method of PBI synthesis was then developed in which the tetraamine was reacted with diphenyl isophthalate in refluxing sulfolane. A critical comparison is given of the three synthetic methods used. The scope of the sulfolane solvent system for PBI-type syntheses was also explored by examining other tetraamine-diphenyl ester combinations. For cases where low reactivity of monomers or low solubility of products precluded the use of sulfolane, phenyl sulfone proved to be a satisfactory alternative solvent.

REPORT NO: AFML-TR-72-285
ACCESS NO: 201,584
TITLE: POLYPHENYLQUINOXALINES FROM HIGHLY
FUSED TETRAAMINES

AD 912 166L

June 1973

AUTHOR(S): F. L. Hedberg; R. F. Kovar; F. E. Arnold
CONTRACTOR: Internal
PROJECT MONITOR: F. E. Arnold (AFML/MBP)
PROJECT NO: 7340
TASK NO: 734004

ABSTRACT: A series of polyphenylquinoxalines has been synthesized by the reaction of p,p'-oxydibenzil with aromatic tetraamines containing varying numbers of fused rings. In addition, it was found that the glass transition temperatures of the resultant polymers increased as the number of adjacent fused rings in the polymers was increased. This provided the basis for achieving glass transition temperatures for the polymers in excess of 400°C, substantially higher than the state-of-the-art polyphenylquinoxalines. All of the polymers displayed both the good thermal stability and the solubility in m-cresol characteristic of the polyphenylquinoxaline family of polymers.

REPORT NO: AFML-TR-73-17 AD 759 525
 ACCESS NO: 201, 357 January 1973
 TITLE: ANALYSIS OF THE THERMAL RESPONSE OF
 PROTECTIVE FABRICS
 AUTHOR(S): H. L. Morse; J. G. Thompson; K. J. Clark;
 K. A. Green; C. B. Moyer
 CONTRACT NO: F33615-72-C-1298
 CONTRACTOR: Acurex Corporation
 PROJECT MONITOR: R. M. Stanton (AFML/MB)
 PROJECT NO: 7320
 TASK NO: 732002

ABSTRACT: The objective of this program was to develop a theoretical and empirical mathematical relationship to define the fabric-skin system's response when exposed to a JP-4 fuel fire. Critical fabric parameters, such as optical, thermochemical and physical characteristics are defined in a manner which will allow the fabric designer to develop improved thermally protective light weight fabrics. The computer code evaluates the model parameter variation in terms of resultant human skin burns. A comparison of the analytical model results with laboratory and fire pit data demonstrates excellent correlation within the limits of the present study.

REPORT NO: AFML-TR-73-26 Volume I AD 766 361
 Volume II AD 766 400
 ACCESS NO: 201, 589 April 1973
 TITLE: LOW COST, FIBER GLASS REINFORCED
 PLASTIC FUEL TANK
 AUTHOR(S): V. A. Chase
 CONTRACT NO: F33615-70-C-1636
 CONTRACTOR: Whittaker Corporation
 PROJECT MONITOR: T. J. Reinhart; S. Marolo (AFML/MB)
 ABSTRACT: Fiber glass reinforced plastic composite fuel tanks (300 gal.) for the A7D aircraft were developed and tested. The primary objective of this program was to demonstrate feasibility of utilizing fiber reinforced plastic composite materials for fabrication of aircraft tankage on a production basis at low cost. This objective was satisfactorily met. A Plywrapping fabrication process in combination with a cost effective design and inexpensive materials selection resulted in a tank considerably lower in cost than the metal equivalent. Fatigue data for the composite and adhesive bonded materials utilized in fabrication of the tank was developed. Analysis of the tank involving loads, weight, stress, nesting, and tank volume was performed. Procedure and results of these analyses are reported.

AFML/MB

REPORT NO: AFML-TR-73-27 AD 913 775L
ACCESS NO: 78,559 August 1973
TITLE: THE THERMAL RESPONSE OF PBI AND NOMEX
II FABRICS EXPOSED TO A JP-4 FUEL FIRE
AUTHOR(S): R. M. Stanton
CONTRACTOR: Internal
PROJECT MONITOR: R. M. Stanton (AFML/MBC)
PROJECT NO: 7320
ABSTRACT: The thermal performance of PBI and Nomex II
fabrics is modeled mathematically. The two fabrics were evaluated for
heat transfer in the laboratory and for protection against burns in full-scale
JP-4 fuel fires. The mathematical and laboratory heat transfer analysis
demonstrates why PBI fabrics provide better burn protection when compared
to Nomex II fabrics. The thermal protection difference between the two
fabrics is caused by the afterflaming and the poorer thermal stability associ-
ated with the Nomex II fabrics. PBI fabrics also provide better thermal
protection than Nomex II fabrics because the heat required to dissipate the
greater moisture content of the PBI fabrics is not available to cause burns.

REPORT NO: AFML-TR-73-28
ACCESS NO: 202,149 January 1973
TITLE: EVALUATION OF PBI AND NOMEX II FOR AIR
FORCE FLIGHT SUITS
AUTHOR(S): R. M. Stanton; S. Schulman; J. H. Ross
CONTRACTOR: Internal
PROJECT MONITOR: R. M. Stanton; S. Schulman (AFML/MBC)
PROJECT NO: 7320
TASK NO: 732002
ABSTRACT: The objective of this evaluation was to determine
the thermal protection and other characteristics of PBI and Nomex II fabrics
intended for use in summer weight AF flight suits. Flight suits made from
the fibers were subjected to full scale JP-4 fuel fires and their thermal pro-
tection characteristics were defined in terms of percent body area damaged.
PBI flight suits provided substantially more thermal protection than did No-
mex II flight suits. Thermal gravimetric analysis and mass spectrometric
analysis shows that Nomex II polymer is fundamentally less stable than the
PBI polymer.

REPORT NO: AFML-TR-73-38 AD 912 948L
 ACCESS NO: 201,679 June 1973
 TITLE: CATIONIC POLYMERIZATION OF VINYL¹
 SUBSTITUTED MONOMERS WITH a, a, a¹, a¹ -
 TETRAPHENYL-P-XYLYL BISCARBONIUM
 HEXACHLOROANTIMONATE
 AUTHOR(S): F. L. Hedberg
 CONTRACTOR: Internal
 PROJECT MONITOR: F. E. Arnold (AFML/MBP)
 PROJECT NO: 7340
 TASK NO: 734004
 ABSTRACT: The hexachloroantimonate salt of the a, a, a¹, a¹ -
 tetraphenyl-p-xylyl biscarbonium ion has been investigated as an initiator of
 cationic polymerization of vinyl compounds. This biscarbonium ion salt
 was found to be ineffective for initiating polymerization of vinyl aliphatic
 compounds, but effective for initiating polymerization of vinyl ethers. The
 mechanism of vinyl ether polymerization with this initiator was studied by
 end-capping reactions. The initiator was found to be incorporated into the
 polymer indicating an addition mechanism, but no evidence of end-capping
 groups was found, indicating the absence of "living" dicationic polymer
 chains.

REPORT NO: AFML-TR-73-39 AD 759 560
 ACCESS NO: 201,373 February 1973
 TITLE: THE EFFECT OF WEAR ON THE COMPRESSIVE
 STRESS IN THE SPHERE-ON-PLANE AND
 MULTIPLE-FLAT-ON-CURVE CONFIGURATIONS
 AUTHOR(S): K. R. Mecklenburg
 CONTRACT NO: F33615-72-C-1374
 CONTRACTOR: Midwest Research Institute
 PROJECT MONITOR: F. C. Brooks (AFML/MBT)
 PROJECT NO: 7340; 7343
 ABSTRACT: Graphite fluoride, a proposed solid lubricant materi-
 al, performed differently on two types of machines. A burnished film of
 graphite fluoride was used to lubricate the sphere-on-plane (pin-on-disc) and
 multiple-flat-on-curve (Falex) test configurations. Compressive stress and
 sphere wear volume were determined as a function of time from the wear scar
 area on the sphere, measured at various times. Friction coefficients were
 also determined for the sphere-on-plane test. The initial and final (static)
 compressive stress values for the multiple-flat-on-curve test configuration
 were determined. Differences in wear scar areas on the two faces of the vee
 block were observed. The large difference in performance of graphite fluor-
 ide on the two test configurations was concluded to be due to the extreme
 difference in contact stresses that existed during the wear tests.

AFML/MB

REPORT NO: AFML-TR-73-42
ACCESS NO: 201,616 May 1973
TITLE: NONPARAMETRIC AND EXTREMAL STATISTICS
IN EARLY FAILURE ANALYSIS WITH UNEQUAL
SAMPLE SIZES
AUTHOR(S): A. S. Heller; R. A. Heller
CONTRACT NO: F33615-72-C-2111
CONTRACTOR: Virginia Polytechnic Institute
PROJECT MONITOR: K. L. Jerina (AFML/MBM)
PROJECT NO: 7340
TASK NO: 734003
ABSTRACT: In the past, early failure analysis has been limited
to either single samples or to samples of identical size. The technique
is here extended to unequal size samples and its use is illustrated with the
graphical and analytical determination of parent population parameters
from first and second fatigue failure data.

REPORT NO: AFML-TR-73-54
ACCESS NO: 201,554 April 1973
TITLE: SAPPHIRE FILAMENTS
AUTHOR(S): B. Siegel; C. R. Mitchell
CONTRACT NO: F33615-72-C-1225
CONTRACTOR: Tyco Laboratories, Incorporated
PROJECT MONITOR: W. Gloor (AFML/MBM)
ABSTRACT: Using the Tyco developed EFG crystal growing
technique, continuous lengths of ruby, $\text{Al}_2\text{O}_3\text{-Ti}_2\text{O}_3$, and $\text{Al}_2\text{O}_3\text{-BeO}$
eutectic filaments were grown and tensile tested at temperatures up to
 1300°C . Results exhibited an improvement in high temperature tensile
strength for systems containing 0.9 wt % Cr in Al_2O_3 . Elevated temperature
strength enhancement was also attempted via the isothermal precipitation
hardening of star sapphire filament containing 0.2 wt % Ti in Al_2O_3 . Evi-
dence of precipitation was noted, but no strength enhancement was achieved.
In addition, a method of reducing strength sensitivity to surface abrasion
via surface alloying was evaluated and flame polishing techniques (used to
heal minor surface flaws) were improved in such a manner to yield strength
improvement of up to 200 ksi for as-grown sapphire filament, resulting in
samples which exhibited strength in excess of 600 ksi.

REPORT NO: AFML-TR-73-65 AD 911 880L
ACCESS NO: 77,605 February 1973
TITLE: FUNDAMENTAL STUDIES ON REACTIVE OLIGOMERS
AUTHOR(S): G. F. D'Alelio
CONTRACT NO: F33615-72-C-1312
CONTRACTOR: Notre Dame University
PROJECT MONITOR: F. E. Arnold (AFML/MBP)
PROJECT NO: 7342
TASK NO: 734201
ABSTRACT: The research reported in AFML-TR-70-39, Part III was continued. Five new dipolarophilic-terminated oligomeric polyimides were prepared and reacted with the dipole, BDNO, to give some polymers with TGA inflections in air in the 500°C region. Styrene-, allyl-, and phenol-terminated oligomeric polyimides were prepared and epoxidized. The curing the nitrile-terminated oligomers inflections in the catalysts did not yield promising results. The coreaction of dioxane-soluble amine terminated oligomeric polyimides with dioxane soluble anhydride-terminated oligomers appears to offer promising, practical systems having good processability which yield highly thermally stable polyimides as final products.

REPORT NO: AFML-TR-73-68 AD 915 217L
ACCESS NO: 202,425 May 1973
TITLE: EXPLORATORY DEVELOPMENT LEADING TO IMPROVED PHENYLQUINOXALINE POLYMERS
AUTHOR(S): P. M. Hergenrother
CONTRACT NO: F33615-72-C-1077
CONTRACTOR: Boeing Aerospace Company
PROJECT MONITOR: T. J. Aponyi (AFML/MBC)
PROJECT NO: 7340
TASK NO: 734003
ABSTRACT: This program was concerned with the development of polyphenylquinoxalines for use as high temperature structural resins. Initially, high molecular weight phenylquinoxaline polymers were prepared in solution for application work. Films cast from these polymer solutions exhibited excellent weight retention after aging for 1000 hours at 316°C in circulating air and also good retention of flexibility and color after aging greater than 400 hours at 316°C in circulating air. A lesser effort was devoted to the fabrication and testing of flat unidirectional laminates using a high modulus graphite reinforcement. The major synthetic effort involved the preparation of several new reactants containing latent crosslinking sites. Several new polyphenylquinoxalines were prepared from these novel reactants.

REPORT NO: AFML-TR-73-70 AD 770 028
ACCESS NO: 202,052 July 1973
TITLE: FRICTION AND WEAR CHARACTERISTICS OF
SOME GRAPHITE FIBER REINFORCED PLASTIC
COMPOSITES

AUTHOR(S): B. D. McConnell; R. J. Dauksys
CONTRACTOR: Internal
PROJECT MONITOR: B. D. McConnell (AFML/MBT);
R. J. Dauksys (AFML/MBC)

PROJECT NO: 7340; 7343
TASK NO: 734003; 734302

ABSTRACT: A series of fiber reinforced composites were investigated to determine their tribological properties under unidirectional sliding motion. The composite formulations consisted of graphite fibers of varying properties and three resin matrices. The graphite fibers selected for studies included Thornel 25, Thornel 40, and Thornel 50, and were fabricated into test panels utilizing an epoxy, a phenolic, and a polyimide resin. The resulting composite panels were used to provide friction and wear specimens of varying fiber orientation for evaluation in a dual rub-shoe test device with the composite block specimens sliding against a rotation metal specimen. Data obtained indicate these composite materials show feasibility for low friction and wear materials for low to moderate temperature, loads, and speeds. Trends in lubrication performance and effects of fiber orientation were masked by problems arising from delamination of the composite specimens due to high unit stresses resulting from line contact with the rotating metal bearing specimen.

REPORT NO: AFML-TR-73-71 AD 766 702
ACCESS NO: 201,735 June 1973
TITLE: STUDY OF SOFT X-RAY APPEARANCE
POTENTIAL SPECTROSCOPY FOR CHEMICAL
ANALYSIS OF SURFACES

AUTHOR(S): W. L. Baun; M. B. Chamberlain
CONTRACTOR: Internal
PROJECT MONITOR: W. L. Baun (AFML/MBM)

PROJECT NO: 7340
TASK NO: 734002

ABSTRACT: A soft x-ray appearance potential spectrometer (SXAPS) has been assembled, tested, and used to record spectra of selected materials for the purpose of studying the feasibility of routine elemental and chemical characterization of surfaces. These initial results demonstrate capabilities of SXAPS as a surface analysis tool and provide guidelines for the development of a more sensitive detection system for the technique. Characteristics of the SXAP spectrometer and criteria for the development of a detection system with an improved dynamic range of sensitivity are presented.

AFML/MB

REPORT NO: AFML-TR-73-72 AD 767 898
ACCESS NO: 201,775 July 1973
TITLE: IMPROVED SILICONE FLUIDS AS CANDIDATE
GAS TURBINE ENGINE OILS FOR -40°F to
465°F TEMPERATURE RANGE
AUTHOR(S): G. J. Morris
CONTRACTOR: Internal
PROJECT MONITOR: G. J. Morris (AFML/MBT)
PROJECT NO: 7343
TASK NO: 734303
ABSTRACT: A physical and chemical laboratory study of several
silicone fluids that represent some of the latest technology in the area has
been conducted. These fluids were an alkyl methyl silicone, a trifluoro-
propyl methyl silicone and a methyl silicone improved by the use of additive
formulation. These fluids were investigated for possible use as candidate
gas turbine engine oils in the temperature range of -40°F to +465°F.
The viscosity-temperature characteristics, volatility, oxidative stability
corrosion reactivity towards selected metals and lubrication capabilities
were assessed for conformance with the recently established specification,
MIL-L-27502, covering the aforementioned temperature range. The alkyl
methyl silicone, although having favorable rheological and lubrication be-
havior, was so oxidatively unstable and corrosion prone that further study
is not recommended. Both trifluoropropyl methyl silicone and improved
methyl silicone have demonstrated sufficient oxidation and corrosion stabili-
ty to warrant further study.

REPORT NO: AFML-TR-73-74 Part II
ACCESS NO: 202,203 November 1973
TITLE: HIGH STRENGTH, HIGH MODULUS AlB_2 FLAKE
REINFORCED COMPOSITES
AUTHOR(S): J. Economy; L. Wohrer; A. Wosilait
CONTRACT NO: F33615-72-C-1496
CONTRACTOR: The Carborundum Company
PROJECT MONITOR: C. E. Browning (AFML/MBC)
PROJECT NO: 7340
TASK NO: 734003
ABSTRACT: The development of high strength, high modulus
 AlB_2 flake reinforced composites with properties isotropic in the plane of
the flakes, was continued. Parameters affecting yields and dimensions of
flakes were investigated. The use of non-aqueous solvent in flake elutriation
was explored. Binary AlB_2 composites were prepared and tested to broaden
the information on their mechanical behavior. A wide range of ternary
composites containing flakes between plies of graphite fibers were investigated.

AFML/MB

REPORT NO: AFML-TR-73-76 AD 910 162L
ACCESS NO: 201,565 April 1973
TITLE: EXPLORATORY DEVELOPMENT OF MATERIALS
RESISTANT TO SUPERSONIC RAIN AND SAND
EROSION

AUTHOR(S): N. E. Wahl
CONTRACT NO: F33615-72-C-1603
CONTRACTOR: Bell Aerospace Company
PROJECT MONITOR: G. F. Schmitt, Jr. (AFML/MBE)
PROJECT NO: 7340
TASK NO: 734007

ABSTRACT: Development and evaluation studies were carried out on ceramic and boride coatings capable of providing erosion protection for titanium blades for the compressor portions of turbine engines. The optimum coating exhibited a four hundred percent increase in sand erosion over uncoated titanium. Rain erosion tests on multilayer coatings of polyurethane indicated that a soft polyurethane over a harder polyurethane coating resulted in improved rain erosion resistance. The solid particle erosion characteristics of various types of materials at 40° and 90° were examined at velocities ranging from 200-730 ft/sec to obtain experimental data for use in analytical modeling studies. The use of flash x-ray, pulsed lasers and holographic methods to "freeze" the transient damage occurring on the eroding specimens was examined as well as high speed photographic techniques.

REPORT NO: AFML-TR-73-78 AD 910 462L
ACCESS NO: 201,566 April 1973
TITLE: CHEMICAL, PHYSICAL AND MECHANICAL
PROPERTIES OF LOW DENSITY PHOSPHATE
ESTER HYDRAULIC FLUIDS

AUTHOR(S): F. Brooks; H. Schwenker
CONTRACTOR: Internal
PROJECT MONITOR: F. C. Brooks; H. Schwenker (AFML/MBT)
PROJECT NO: 7340
TASK NO: 734008

ABSTRACT: Three low density phosphate ester fluid candidates, MLO-70-32, MLO-70-62, and MLO-71-37, were characterized as to their physical and chemical properties. MLO-71-37 which exhibited the most acceptable characteristics was further evaluated for its reactions in simulated functional and system environments. MLO-71-37 was found to possess the most satisfactory overall properties and exhibited potential operational capability over a temperature range of -65 to 275°F. All three candidate fluids displayed a sensitivity to elastomeric materials with specific manufacturer and compound designations required for satisfactory performance.

AFML/MB

REPORT NO: AFML-TR-73-81 AD 760 770
ACCESS NO: 201,568 April 1973
TITLE: THE COMPUTATION OF THE BULK MODULI OF A
SYNTHETIC HYDROCARBON HYDRAULIC FLUID
AUTHOR(S): F. C. Brooks
CONTRACTOR: Internal
PROJECT MONITOR: F. C. Brooks (AFML/MBT)
PROJECT NO: 7340
TASK NO: 734008
ABSTRACT: The bulk moduli of a synthetic hydrocarbon are
calculated and appropriate equations are presented. Methods of determining
and predicting bulk moduli are reviewed. A conservative low value of iso-
thermal secant bulk modulus of the synthetic hydrocarbon candidate was
selected from determinations produced with the Klaus apparatus. This select-
ed value served from the primary datum point for calculating isothermal
secant and tangent bulk moduli and adiabatic secant and tangent bulk moduli.
The results of these calculations are presented in tabular and graphical form
for temperatures of 100, 200, 275, 300, 400 and 500°F and pressures
between 0 and 5000 psig.

REPORT NO: AFML-TR-73-90 AD 913 831L
ACCESS NO: 201,782 March 1973
TITLE: LONG LIFE ELASTOMERIC AIRCRAFT
HYDRAULIC SEALS
AUTHOR(S): L. G. Hiltner; K. R. Miller; K. T. Ksieski
CONTRACT NO: F33615-71-C-1304
CONTRACTOR: Parker-Hannifin Corporation
PROJECT MONITOR: L. M. Peterson (AFML/MBE)
PROJECT NO: 7340
TASK NO: 734005
ABSTRACT: The purpose of this investigation was to continue
development of a material for long life, high temperature, elastomeric
hydraulic seals. An experimental low temperature, low set fluorocarbon
compound met all of the objectives of the initial program and a nitrile com-
pound with outstanding heat stability showed promise of being successful.
The surprising performance of the fluorocarbon compound at low temperature
in the rod test fixture prompted the use of a piston type seal rig to better
evaluate the low temperature capabilities of the compounds. Therefore both
a rod and a piston test fixture were used in this program for functional
testing.

AFML/MB

REPORT NO: AFML-TR-73-96 AD 914 417L
ACCESS NO: 202,002 May 1973
TITLE: HIGH PRESSURE PROCESSING OF ABLATIVE
MULTIDIRECTIONAL REINFORCED PLASTIC
COMPOSITES
AUTHOR(S): G. P. Lang; H. A. Holman; A. W. Kallmeyer
CONTRACT NO: F33615-72-C-1684
CONTRACTOR: McDonnell Douglas Astronautics Company
PROJECT MONITOR: H. P. Materne (AFML/MBC)
PROJECT NO: 7340
TASK NO: 734001

ABSTRACT: The program involved the exploratory development of ablative composite materials by high pressure centrifugal impregnation of multidirectional 3-D woven carbon fiber preforms with aromatic heterocyclic polymers. The resultant heat shield composites were characterized for ablative, mechanical, thermophysical and nuclear-related properties. The centrifugal impregnation process is based on mounting a preform and resin in a centrifuge which is contained inside an oven. The cure cycle is then conducted while the materials are held under centrifugal pressure and at an elevated temperature. Centrifugal impregnation produces high density composites in one 15 to 30 hour process cycle. This is its main advantage over all other impregnation methods which typically require three or more impregnation cycles. The centrifugal pressure tends to force the resin solids into a preform while at the same time accelerating the rate at which the bubbles of gas produced by the resin cure reaction are removed.

REPORT NO: AFML-TR-73-99
ACCESS NO: 201,999 August 1973
TITLE: MOLECULAR WEIGHT DISTRIBUTION, MORPHOL-
OGY, AND MECHANICAL BEHAVIOR OF SELECTED
PBI FIBERS
AUTHOR(S): D. R. Wiff; M. T. Gehatia; A. Wereta
CONTRACTOR: Internal
PROJECT MONITOR: M. T. Gehatia (AFML/MBP)
PROJECT NO: 7340
TASK NO: 734004

ABSTRACT: The molecular weight distribution (MWD) of three polybenzimidazole (PBI) samples have been determined. These MWD's were inferred from equilibrium sedimentation data using a recently developed technique of regularization for handling the mathematically ill-posed problem. Two of the PBI samples were polymerized by a melt polymerization from monomer purified by different processes. Fibers made from these two samples were subjected to mechanical testing and x-ray diffraction studies. A correlation between mechanical properties, morphology, and MWD is presented. Solution polymerization yielded a polymer with higher MW averages and a broader MWD.

AFML/MB

REPORT NO: AFML-TR-73-100 AD 768 453
ACCESS NO: 201,569 June 1973
TITLE: ANALYTICAL INVESTIGATION OF STRESS CON-
CENTRATIONS DUE TO HOLES IN FIBER
REINFORCED PLASTIC LAMINATED PLATES,
THREE-D MODELS
AUTHOR(S): E. F. Rybicki; A. T. Hopper
CONTRACT NO: F33615-72-C-1239
CONTRACTOR: Battelle Memorial Institute
PROJECT MONITOR: J. M. Whitney (AFML/MBM)
PROJECT NO: 7342
TASK NO: 734202
ABSTRACT: A three-dimensional analysis for the stress distri-
butions around a hole in a laminated plate is presented. The method of
stress analysis is based on a complementary energy formulation with three-
dimensional equilibrium finite elements. Numerical verification checks of
the analysis for two-dimensional problems are presented. Material proper-
ties representing boron/epoxy laminas are used. Problems are selected to
show the influence of laminate stacking sequence on the transverse normal
and shear stresses around the hole.

REPORT NO: AFML-TR-73-101 AD 913 231L
ACCESS NO: 201,680 July 1973
TITLE: GRAPHITE FIBER AND BORON NITRIDE FIBER
FILLED POTTING COMPOUNDS
AUTHOR(S): R. J. Dauksys
CONTRACTOR: Internal
PROJECT MONITOR: R. J. Dauksys (AFML/MBC)
PROJECT NO: 7340
TASK NO: 734004
ABSTRACT: Preliminary information and data are presented
which show how the thermal, electrical, and mechanical properties of epoxy
potting compounds may be controlled by the addition of discontinuous fibrous
reinforcements of high modulus graphite and/or boron nitride. The reduc-
tion of α of an epoxy potting compound utilizing graphite and/or BN Fibers
is shown to be a function of modulus of fibers and negative α of fibers
along their length, as well as quantity of fibers used.

REPORT NO: AFML-TR-73-104 AD 914 168L
ACCESS NO: 201,846 August 1973
TITLE: THE EFFECTS OF ENVIRONMENTAL EXPOSURE
ON STRENGTH PROPERTIES OF AF-A-3639
ADHESIVE BONDED JOINTS

AUTHOR(S): T. J. Aponyi
CONTRACTOR: Internal
PROJECT MONITOR: T. J. Aponyi (AFML/MBC)
ABSTRACT: A new adhesive AF-A-3639 (Hysol's ADX-639)
which was developed under AF contract as a 420° F capability tough adhesive
was characterized for its durability when exposed to hostile environments
such as heat aging plus salt spray, humid aging, humid aging and elevated
temperature cycling, and fatigue. Specimens used in the evaluation were
aluminum-to-aluminum and titanium-to-titanium. The adhesive exhibited
excellent retention of initial strength after all the tests except for the tests
at 420° F with Ti specimens. However, these lower strength levels were
attributed to the cold phosphate etch used as a pretreatment for the Ti
adherends.

REPORT NO: AFML-TR-73-115
ACCESS NO: 201,687 July 1973
TITLE: ELASTICITY SOLUTIONS FOR FIBER-
REINFORCED, POLYMERIC COMPOSITE
LAMINATES

AUTHOR(S): R. D. Schile
CONTRACT NO: F33615-72-C-1387
CONTRACTOR: Dartmouth College
PROJECT MONITOR: J. M. Whitney (AFML/MBM)
PROJECT NO: 7342
TASK NO: 734202
ABSTRACT: The objective of this program is the determination
of the state of stress in laminated, rectangular plates in which the individual
plies are composed of fiber-reinforced, polymeric material. Both static
and dynamic loads are to be considered. The continuity conditions between
plies are taken into account by means of an integral formulation of three-
dimensional stress function theory. For unsymmetrically laminated plates,
equations governing the coupled bending and stretching deformation have
been derived. Solutions of these equations are exhibited for the cases of
loading by uniformly distributed edge forces and moments and a uniform
temperature.

REPORT NO: AFML-TR-73-118
 ACCESS NO: 201,617 June 1973
 TITLE: PRESTRESSING OF BORON AND GRAPHITE
 EPOXY PREPREG FOR COMPOSITE STRENGTH
 IMPROVEMENT
 AUTHOR(S): G. J. Mills; G. G. Brown; D. D. Waterman
 CONTRACT NO: F33615-72-C-1614
 CONTRACTOR: Northrop Research and Tech Center
 PROJECT MONITOR: R. J. Dauksys (AFML/MBC)
 PROJECT NO: 7340
 ABSTRACT: Production boron fibers have wide variations in tensile strength due, in part, to defects along the fiber length. The "tail" of the fiber strength distribution appears to control the composite strength level and dispersion in property values. The "prestressing process" selectively prebreaks the fibers at these defect sites while the material is in the prepreg, tape condition, thereby increasing the average fiber strength with a reduced standard deviation. The effects of various processing parameters were evaluated to demonstrate the validity and reproducibility of the prestress method for upgrading commercial AVCO 5505 and 3M SP272, 4.0 and 5.6 mil boron epoxy, prepreg material through alterations in the fiber strength distributions. Fiber improvements are shown to translate into laminates as significant increases in levels. Unidirectional laminate tension test results at large sample sizes are compared for two levels of prepreg quality, drawn from production quantities.

REPORT NO: AFML-TR-73-121 AD 768 924
 ACCESS NO: 201,884 April 1973
 TITLE: GRAPHITE FLUORIDE -- A PROPOSED
 SOLID LUBRICANT
 AUTHOR(S): K. R. Mecklenburg; B. D. McConnell
 CONTRACT NO: F33615-72-C-1374
 CONTRACTOR: Midwest Research Institute
 PROJECT MONITOR: F. C. Brooks (AFML/MBT)
 PROJECT NO: 7340 and 7343
 ABSTRACT: Graphite fluoride, a proposed solid lubricant material, was evaluated with a sphere-on-plane tester to determine if previously generated data could be reproduced. Preliminary experiments with (CF)_{xn} (graphite fluoride), substituted into existing film formulations in place of MoS₂, were revealed extremely short wear-lives when other test geometries were used. However, with the sphere-on-plane configuration, the data previously reported were reproduced. Wear-lives and friction coefficients for burnished MoS₂ and (CF)_{xn} are presented, along with friction coefficients for the bare metal combinations used. Also included are compressive stress values in the test zone based upon the starting and finishing contact areas.

AFML/MB

REPORT NO: AFML-TR-73-127 AD 766 330
ACCESS NO: 201,682 May 1973
TITLE: MODEL COMPOUNDS FOR FLUORINATED
POLYMERS AND FLUIDS
AUTHOR(S): R. D. Chambers; W. K. R. Musgrave;
R. P. Corbally; E. Marper; S. Partington
CONTRACT NO: F61052-69-C-0010
CONTRACTOR: University of Durham
PROJECT MONITOR: C. Tamborski (AFML/MBP)
PROJECT NO: 7342
TASK NO: 734201
ABSTRACT: This work is concerned with the preparation of
model compounds based on the reactions of tetrafluoropyridazine and
pentafluoropyridine with fluorinated olefins, acetylenes or ketones. The
compounds which have been synthesized have been tested as to their thermal
and oxidative stability.

REPORT NO: AFML-TR-73-130 AD 911 810L
ACCESS NO: 77,604 June 1973
TITLE: THE FLAMMABILITY, THERMAL STABILITY,
AND DYEABILITY PROPERTIES OF HIGH
TEMPERATURE ORGANIC FIBERS
AUTHOR(S): N. J. Abbott; J. S. Panto; J. Skelton; M. M.
Schoppee
CONTRACT NO: F33615-71-C-1287
CONTRACTOR: Fabric Research Labs
PROJECT MONITOR: S. Schulman (AFML/MBC)
PROJECT NO: 7320
TASK NO: 732002
ABSTRACT: The prime objective of the work was to devise means
for dyeing PBI and rendering it dimensionally stable to exposure in a JP-4
fuel fire for several seconds. A technique for dyeing with dispersend, acid
or acid metallized dyes was developed, permitting a wide range of colors to
be used, and specifically bends of dyes to produce Sage Green and Air Force
Blue shades. One of the Sage Green formulations, using acid metallized dyes,
was capable of withstanding several seconds in a JP-4 fire without excessive
dye sublimation. A treatment which could be incorporated into the dyebath
was also developed which rendered PBI fabric essentially nonshrinking in a
JP-4 fire. A preliminary study of the mechanical properties of flame-
resistant fabrics when subjected to a high heat flux was also carried out.

AFML/MB

REPORT NO: AFML-TR-73-134 AD 769 342
ACCESS NO: 201, 932 September 1973
TITLE: PROTON MAGNETIC SPECTRA OF
POLY(M-PHENYLENE BIBENZIMIDAZOLE)-
LITHIUM CHLORIDE SOLUTIONS IN
DIMETHYLACETAMIDE
AUTHOR(S): M. T. Ryan; T. E. Helminiak
CONTRACTOR: Internal
PROJECT MONITOR: T. E. Helminiak (AFML/MBP)
PROJECT NO: 7340
TASK NO: 734004
ABSTRACT: The solubility of high temperature polymers is an extremely important property governing, in many cases, the extent to which a polymer can be utilized. For poly(meta-phenylene bibenzimidazole), PBI, N, N-dimethyl acetamide (DMAC) has been a useful solvent; however, the solubility of the polymer is enhanced by the addition of lithium chloride and this procedure is used in the preparation of fiber spinning dopes for PBI. Lithium chloride has been shown to have a concentration dependent effect on this chemical shift, increasing the shift through a maximum and then decreasing at higher concentrations of lithium chloride. Similar effects have been found for lithium bromide. These chemical shift changes are attributed to conformational changes in the polymer and can provide a measure of the degree of expansion of the macromolecule.

REPORT NO: AFML-TR-73-142
ACCESS NO: 201, 774 July 1973
TITLE: FRACTURE OF GRAPHITE FIBER REINFORCED
COMPOSITES
AUTHOR(S): F. J. Mandell; F. F. Wang; J. J. McGarry
CONTRACT NO: F33615-72-C-1686
CONTRACTOR: M. I. T.
PROJECT MONITOR: R. J. Dauksys (AFML/MBC)
PROJECT NO: 7340
TASK NO: 734003
ABSTRACT: The fracture of thin, prenotched graphite/epoxy/ laminates has been studied analytically and experimentally. The analytical portion of the study has concentrated on a three-dimensional finite element analysis of the crack problem in anisotropic laminates featuring a two-stage solution employing a hybride model multilayered element. Experiments were performed to investigate the applicability of classical fracture mechanics, the characteristics of crack tip damage during loading, and the final modes of crack propagation for representative ply configurations of graphite/epoxy/ laminates. The development of the subcritical zone into a final catastrophic fracture mode is also described.

AFML/MB

REPORT NO: AFML-TR-73-144, Part I
ACCESS NO: 201,619 May 1973
TITLE: PERFLUOROCARBON EPOXIDES, PART I
AUTHOR(S): R. J. De Pasquale; C. D. Padgett; J. R. Patton
CONTRACT NO: F33615-72-C-1550
CONTRACTOR: PCR, Incorporated
PROJECT MONITOR: R. C. Evers (AFML/MBPL)
PROJECT NO: 7340
TASK NO: 734004
ABSTRACT: Studies directed toward the preparation of a 2,3 spiroepoxide were culminated by the synthesis of perfluoro (1-oxaspiro (2,3) hexane). A new class of compound, a perfluorinated ether epoxide, was prepared by the oxidation of the vinyl ether derived from HFPO trimer. Several approaches leading to the preparation of perfluorinated-N-alkyl aziridines were investigated.

REPORT NO: AFML-TR-73-147, Part I AD 913 098L
ACCESS NO: 201,693 June 1973
TITLE: GRAPHITE FIBERS FROM PITCH
AUTHOR(S): R. Didchenko
CONTRACT NO: F33615-71-C-1538
CONTRACTOR: Union Carbide Corporation
PROJECT MONITOR: W. Gloor (AFML/MBC)
PROJECT NO: 7320
TASK NO: 732001
ABSTRACT: The effort under this contract is being conducted to develop a continuous process for producing high-modulus carbon fibers from an inexpensive commercial pitch precursor. Petroleum pitches have been identified as the most promising precursors for the process. The pitches have been modified to increase their P.I. content while maintaining good flow properties. Multifilament tow and monofilaments with diameters ranging from 50 microns down to 10 microns have been spun from the modified pitches. Initial experiments have demonstrated that it is feasible to process the multifilament yarn continuously through a series of heat-treatment stages.

AFML/MB

REPORT NO: AFML-TR-73-154 AD 913 178L
ACCESS NO: 201, 789 July 1973
TITLE: HIGH TEMPERATURE POLYMERIC
COATING MATERIALS

AUTHOR(S): J. P. King, J. Stinkin; G. H. Dahl
CONTRACT NO: F33615-72-C-1662
CONTRACTOR: Pennwalt Corporation
PROJECT MONITOR: R. L. Stout; D. E. Prince (AFML/MBE)

ABSTRACT: The objective of this program was to develop and evaluate organic and semi-organic polymeric materials for use as coatings which could be cured at low temperatures and possess thermal stability up to 1000° F. The best overall performance was shown by paint systems based on: $Zr(OH)_2 [OP(Me)(Ph)O]_2 / Ph_2P-(O)OH/TiO_2$; $ZnCl_2 / Ph(PhSO_2C_6H_4)P(O)OH/Me(Ph)P(O)OH/TiO_2$; and $Zn [OP(C_6H_4N_2)(Ph)O]_{0.5} OP(Me)^4(Ph)O_{1.5} / Al$. These formulations can be cured into hard, cohesive coatings by brief heating at 150° and 200° C. Heating at 540° C for prolonged periods of time does not alter the integrity and functionality of the coatings although changes in their composition take place at elevated temperatures. Both thermal stability and mechanical properties of coatings based on poly(metal phosphinates) were found superior to those of silicone-based formulations.

REPORT NO: AFML-TR-73-162
Volume I AD 915 591L
Volume II AD 915 592L
ACCESS NO: 201, 620 July 1973
TITLE: QUALITY ASSURANCE FOR ADVANCED
COMPOSITE AIRCRAFT STRUCTURES

AUTHOR(S): L. R. Sanders
CONTRACT NO: F33615-71-C-1359
CONTRACTOR: McDonnell Douglas
PROJECT MONITOR: R. M. Neff (AFML/LC); G. E. Husman (AFML/MB)
PROJECT NO: 6169 CW

ABSTRACT: The objective of this program was to provide confidence in the structural integrity of composite empennage type structure characterized as full depth honeycomb core sandwiched between composite laminate skins by demonstrating the validity of quality assurance procedures and proving the adequacy of NDT techniques. The first volume of this report is a detailed description of the entire program. The second volume is a quality assurance manual detailing all the necessary procedures for fabrication and inspection of sound composite empennage structure.

AFML/MB

REPORT NO: AFML-TR-73-168 AD 913 257L
ACCESS NO: 201, 733 June 1973
TITLE: NEW POLYMER-FORMING REACTIONS
FOR FLUOROCARBONS
AUTHOR(S): M. S. Toy; R. S. Stringham
CONTRACT NO: F33615-72-C-1423
CONTRACTOR: Stanford Research Institute
PROJECT MONITOR: C. Tamborski (AFML/MBP)
PROJECT NO: 7342
TASK NO: 734201
ABSTRACT: The objective of this program is to study the synthesis and reaction of selected perfluorocompounds containing perfluoroolefinic ($-\text{CF}=\text{CF}_2$) and fluoroxy ($-\text{OF}$) functional groups adaptable to polymerization reactions. Of theoretical nature is the contrast mechanism between the well known nucleophilic additions of fluoroanions F^- to perfluoroolefins and the electrophilic fluoroxy addition reactions to confirm the fluoronium ion F^+ addition mechanism for the latter.

REPORT NO: AFML-TR-73-169 AD 767 631
ACCESS NO: 201, 776 July 1973
TITLE: AN INEXPENSIVE UNIVERSAL STEPPING
MOTOR CONTROLLER
AUTHOR(S): D. E. Wisnosky; J. S. Solomon
CONTRACT NO: F33615-72-C-1372
CONTRACTOR: University of Dayton
PROJECT MONITOR: W. L. Baun (AFML/MBM)
PROJECT NO: 7340
TASK NO: 734002
ABSTRACT: This report describes a universal stepping motor controller that is extremely versatile and can be built inexpensively. Control is provided to run the motor in either forward or reverse directions in single steps, or slew at one of eight set rates. Given a number of steps and number of intervals which are a multiple of the step size, it may be set to scan automatically under external control or manually. Complete circuit operations and construction details are provided as are some example applications.

AFML/MB

REPORT NO: AFML-TR-73-174 AD 768 652
ACCESS NO: 202, 195 July 1973
TITLE: ANALYTICAL MODELING OF LIQUID AND
SOLID EROSION
AUTHOR(S): W. F. Adler
CONTRACT NO: F33615-71-C-1528
CONTRACTOR: Bell Aerospace Company
PROJECT MONITOR: G. F. Schmitt (AFML/MBE)
PROJECT NO: 7342
TASK NO: 734202
ABSTRACT: The analytical model for the erosion of a brittle material by multiple particle impacts is revised in accordance with microscopic observations of the erosion damage due to the direct impact of glass beads. Procedures are described for obtaining the quantitative data required to make the model a predictive tool. Erosion tests were conducted. Excellent agreement was found between the average ring fracture diameter and the diameter of the contact area predicted by the Hertzian theory of impact for the glass beam impacts. The damage mechanisms for glass plates impacted by sand particle and liquid drops were investigated through microscopic examination of the progressively-eroded surfaces. Weight-loss data are available for ultra-high molecular weight polyethylene, nickel-coated glass-fiber reinforced epoxy, and graphite-fiber reinforced epoxy specimens exposed to rain and sand erosion environments.

REPORT NO: AFML-TR-73-175 AD 772 679
ACCESS NO: 202, 204 November 1973
TITLE: INTERACTION BETWEEN PERFLUOROALKYL
POLYETHER LINEAR AND CYCLIC DERIVATIVE
FLUIDS AND HIGH TEMPERATURE BEARING STEELS
IN OXIDATION-CORROSION ENVIRONMENT
AUTHOR(S): G. J. Morris
CONTRACTOR: Internal
PROJECT MONITOR: G. J. Morris (AFML/MBT)
PROJECT NO: 7343
TASK NO: 734303
ABSTRACT: This report describes the interaction between perfluoroalkyl polyether linear and cyclic derivative fluids and a high temperature bearing steel, WD-65, among others, studied in a laboratory oxidation-corrosion environment. Temperature ranges of 500° F to 700° F were covered by this investigation. Two hardness levels of WD-65 alloy showed little reactivity with the perfluorinated fluids as well as with dissimilar and ferrous metals up to 700° F. The WD-65 did not catalyze the failure of either dissimilar or ferrous alloys nor did it interfere with additive response in the fluids. It was substantially less reactive than M-50 to 52100 bearing steel alloys in the perfluorinated fluids of interest.

AFML/MB

REPORT NO: AFML-TR-73-179
ACCESS NO: 202,073 July 1973
TITLE: STUDIES ON THE VISCOELASTIC BEHAVIOR OF
FIBER REINFORCED PLASTIC
AUTHOR(S): R. A. Schapery; S. W. Beckwith; N. Conrad
CONTRACT NO: F33615-70-C-1260
CONTRACTOR: Texas A&M Research Foundation
PROJECT MONITOR: J. C. Halpin (AFML/MBM)
ABSTRACT: A model for microcrack growth in viscoelastic
fibrous composites is developed and incorporated into a viscoelastic constitu-
tive theory. The applicability of this crack propagation analysis for predicting
the influence of stress history on failure of composites is then examined.
Mechanical behavior of a unidirectional graphite fiber-reinforced epoxy is
characterized in terms of the separate effects of constant and transient temper-
atures fiber angle, single and multiple cycle loading, and stress level. The
nature of the microstructure and a possible crack arrest mechanism are shown
in micrographs obtained with a scanning electron microscope. The Appendix
contains abstracts of three reports which were published during the period
covered by this report.

REPORT NO: AFML-TR-73-180
ACCESS NO: 202,336 August 1973
TITLE: METALLOGRAPHIC CHARACTERIZATION
OF RENE 95 FORGING
AUTHOR(S): N. M. Menon
CONTRACTOR: Internal
PROJECT MONITOR: W. H. Reimann (AFML/LLM)
PROJECT NO: 7351
TASK NO: 735101
ABSTRACT: A metallographic characterization of Rene 95 forgings
has been completed. Rene 95 is a high strength nickel-base super-alloy with
a 1200°F temperature capability primarily used for compressor and turbine
disk applications. In addition to the conventional precipitation and solid solu-
tion strengthening mechanisms, Rene 95 is further strengthened through the
incorporation of thermomechanical processing (TMP). This results in the
formation of a duplex structure consisting of warm worked grains surrounded
by a "necklace" of very fine recrystallized grains thus resulting in superior
tensile and stress-rupture properties. The microstructure consists of γ'
precipitates distributed through the γ matrix with carbides of the MC type
occurring predominantly throughout the necklace regions. A detailed discus-
sion of the morphologies of these phases is presented in the report.

AFML/MB

REPORT NO: AFML-TR-73-188
ACCESS NO: 201,606 July 1973
TITLE: FAILURE MODE ANALYSIS OF
LUBRICATED SATELLITE COMPONENTS
AUTHOR(S): R. J. Benzing; J. R. Strang
CONTRACTOR: Internal
PROJECT MONITOR: R. J. Benzing; J. R. Strang (AFML/MBT)
PROJECT NO: 7343
ABSTRACT: A failure mode analysis performed for lubrication malfunctions or failure in ten different spacecraft identified twelve possible failure modes. These were lubricant degradation, lubricant dewetting, slip ring and brush wear, improper lubricant transfer, inadequate lubricant quantity, lubricant volatility effects, lubricant incompatibility, torque variations, cage and bearing instability, cage wear, lubricant creep and film thickness. This report includes a discussion of a four phase effort required to develop accelerated tests for predicting lubricant life performance in space systems. A program is recommended for the development of accelerated tests to be used in selecting improved long life lubricants for space systems.

REPORT NO: AFML-TR-73-190, Part I
ACCESS NO: 202,197 September 1973
TITLE: RADIANT HEATING OF AEROSPACE MATERIALS.
PART I ANALYSIS OF MATERIALS CONCEPTS
AUTHOR(S): H. Tong; K. E. Suchsland; W. S. Bonnett;
L. Cooper; C. B. Moyer
CONTRACT NO: F33615-72-C-1774
CONTRACTOR: Acurex Corporation
PROJECT MONITOR: R. W. Farmer (AFML/MBC)
PROJECT NO: 7342
TASK NO: 734202
ABSTRACT: An analytical assessment was made of the thermal response of structural and thermally protective materials under intense thermal irradiation. The thermal efficiency and modes of energy dissipation were examined for a wide variety of real and postulated monolithic, layered and char forming composite materials. Cermets, monolithic elemental species, polymers, and composite mixtures were studied using a steady-state surface energy balance code. Structural and thermally protective materials were assessed using a transient in-depth charring ablation code. Axisymmetrical ablation code studies revealed a small two-dimensional heat conduction effect for plastics and good insulators. A reflective copper coating was assumed for boron-epoxy, combinations of graphite and pyrolytic graphite, and a structural metal. A protective organic coating for a reflective copper layer degraded performance by increasing the absorbed flux and undergoing transient ablation for a relatively long period. An approximate method was developed for assessing materials-jet and convective flow interactions.

AFML/MB

REPORT NO: AFML-TR-73-191 AD 915 231L
ACCESS NO: 202,086 August 1973
TITLE: EXPLORATORY DEVELOPMENT OF LOW
THERMAL CONDUCTIVITY CARBON FIBERS
AUTHOR(S): I. L. Kalnin; M. J. Ram; R. Dix; A. J. Manning
CONTRACT NO: F33615-71-C-1541
CONTRACTOR: Celanese Research Company
PROJECT MONITOR: H. M. Ezekiel (AFML/MBC)
PROJECT NO: 7320
TASK NO: 732001
ABSTRACT: Dry carbon fiber thermoconductometric methods
were developed further for use in the range from 0.005 to 0.05 CGSU.
Chemical treatments of commercial high strength graphite fibers with known
intercalating agents did not lower the thermal conductivity sufficiently. A
procedure for spinning carbon-filled PAN precursor was developed and the
effect of preoxidation and processing times explored in detail. The best fibers
made so far had 250 Ksi tensile strength and contained about 5% finely dis-
persed carbon black.

REPORT NO: AFML-TR-73-206
ACCESS NO: 202,074 August 1973
TITLE: INVESTIGATION OF ENERGY-ABSORBING
MECHANISMS IN THE IMPACT BEHAVIOR AND
RAIN EROSION RESISTANCE OF PURE NICKEL
AUTHOR(S): O. G. Engel
CONTRACT NO: F33615-72-C-1620
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: G. F. Schmitt (AFML/MBE)
ABSTRACT: The impact behavior of pure nickel 270 at velocities
of 100 to 432 feet per second with nylon sphere impacts and the rain erosion
resistance at velocities of 100-1100 feet per second in one inch hour rainfall
were investigated to determine the mechanisms whereby nickel absorbs the
energy of the impacts and thereby possesses good erosion resistance.

AFML/MB

REPORT NO: AFML-TR-73-207, Part I AD 913 808L
ACCESS NO: 78,558 August 1973
TITLE: ELECTRICALLY CONDUCTIVE COATING
MATERIALS
AUTHOR(S): D. R. Ulrich; M. J. Noone; E. Feingold;
V. F. Mazzio
CONTRACT NO: F33615-72-C-1657
CONTRACTOR: General Electric Company
PROJECT MONITOR: DEPrince (AFML/MBE)
PROJECT NO: 7340
TASK NO: 734007
ABSTRACT: The objective of this program was to develop special nonmetallic pigment materials for use in the preparation of new and improved electrically conductive or antistatic polymeric coatings. The goals are to produce a white pigment, while suitable for use as a substitute for the carbon black now employed and to develop colored conductive pigment materials which can be formulated into polymeric binders to give conductive visual camouflage coatings. Detailed characterization of the microstructure of these coatings has been performed to establish the mechanism of conduction and to relate microstructure to conductivity. The most successful nonwhite pigment to date has been brown cadmium oxide. Several high conductivity oxides resulted from the doping of ZnO.

REPORT NO: AFML-TR-73-209
ACCESS NO: 202,230 August 1973
TITLE: CRACK TIP STRESS INTENSITY FACTORS IN
FINITE ANISOTROPIC PLATES
AUTHOR(S): M. D. Snyder; T. A. Cruse
CONTRACT NO: F33615-73-C-5055
CONTRACTOR: Carnegie-Mellon University
PROJECT MONITOR: J. M. Whitney (AFML/MBM)
PROJECT NO: 7340
TASK NO: 734003
ABSTRACT: A numerical technique has been derived for determining stress intensity factors in cracked anisotropic plates of finite geometry. Using complex variable methods an exact solution is derived for the problem of unit loads applied to a cracked infinite anisotropic plate. This fundamental solution is used with the boundary-integral equation method for analysis of plates of finite geometry. Numerical results are obtained for center-cracked and double-edge cracked finite width tension specimens using material properties representative of a family of advanced fiber reinforced composite laminates. For these geometries the numerical results indicate that the isotropic stress intensity factor serves as a good approximation for anisotropic materials.

AFML/MB

REPORT NO: AFML-TR-73-217 AD 915 068L
ACCESS NO: 202, 078 October 1973
TITLE: EXPLORATORY DEVELOPMENT OF THE
INVESTIGATION OF METHODS TO PROCESS BBB,
BBL AND RELATED POLYMERS
AUTHOR(S): I. L. Kalnin; C. P. Driscoll; M. L. Druin
CONTRACT NO: F33615-72-C-1642
CONTRACTOR: Celanese Corporation
PROJECT MONITOR: T. E. Helminiak (AFML/MBP)
PROJECT NO: 7340
TASK NO: 734004
ABSTRACT: The processability of different molecular weight
BBB polymers was explored by hot pressing the material, as-received or
modified in various ways, under different conditions and characterizing the
formed specimen by various analytical techniques. The BBB can be densified
without additives to greater than 94% of true density by hot pressing at 400-
500°C and 20-50 thousand psi (Ksi) pressure, but the strength of the neat
product is low, 2-3 Ksi in flexure. Addition of the BBB precursor monomers
as a binder and chopped BBB fiber as a reinforcement increased the flexural
strength to the 8-10 Ksi range. Of potential plasticizing additives explored so
far, the addition of polybenzimidazole (PBI) polymer was the most effective;
the Vat Red 15 dye and SbCl_3 additives also showing some activity. The
fracture surface morphology of the consolidated specimens changes with the
pressing temperature and the nature of the additive. Plastic deformation of
the BBB takes place upon pressing at about 500 C.

REPORT NO: AFML-TR-73-218 AD 913 791L
ACCESS NO: 201, 778 July 1973
TITLE: IMPROVED THERMALLY PROTECTIVE
MATERIALS FOR AIR FORCE FLIGHT JACKETS
AUTHOR(S): W. L. Rooney; R. M. Stanton; J. H. Ross
CONTRACTOR: Internal
PROJECT MONITOR: W. L. Rooney; R. M. Stanton (AFML/MBC)
PROJECT NO: 7320
ABSTRACT: Improved protection provided personnel from air -
craft fires by more thermally stable materials for AF flight jackets is
desirable. By directly exposing various fabric combinations to a JP-4 fuel
fire and monitoring the heat rise behind the fabrics, it was concluded that
materials are available that will provide adequate thermal protection. It was
demonstrated that continuous filament Nomex shell fabric when used with an
insulation layer of 4 oz/yd² Kynol or Nomex batting, and an inner layer of
continuous filament or staple Nomex will provide increased thermal protection
and is an acceptable replacement candidate for the cold weather, K-2B,
jacket. It was also demonstrated that a continuous filament Nomex shell
fabric over an inner layer of Fypro, Durette, or Kynol/Nomex blend will
improve the thermal protection capacity of the moderately cold weather, L2,

ABSTRACT (Cont'd): Jacket. It is concluded that the present materials are adequate, although more fire resistant materials are desirable.

REPORT NO: AFML-TR-73-227 AD 769 448
 ACCESS NO: 202,198 September 1973
 TITLE: ANALYSIS OF RAIN EROSION OF COATED MATERIALS
 AUTHOR(S): G. S. Springer; C. I. Yang; P. S. Larsen
 CONTRACT NO: F33615-72-C-1563
 CONTRACTOR: University of Michigan
 PROJECT MONITOR: G. F. Schmitt (AFML/MBE)
 PROJECT NO: 7340
 TASK NO: 734007
 ABSTRACT: The behavior of coat-substrate systems subjected to repeated impingements of liquid droplets was investigated. The systems studied consisted of a thick homogeneous substrate covered by a single layer of homogeneous coating of arbitrary thickness. Based on the uniaxial stress wave model, the variations of the stresses with time were determined both in the coating and in the substrate. Employing the fatigue theorems established for the rain erosion of homogeneous materials, algebraic equations were derived which describe the incubation period, and the mass loss of the coating past the incubation period, in terms of the properties of the droplet, the coating and the substrate. Good agreement was found between the present analytical results and the data. Difference between the uniaxial stress wave and the uniaxial strain wave models were also evaluated by calculating according to both models.

REPORT NO: AFML-TR-73-236
 ACCESS NO: 202,331 September 1973
 TITLE: STUDIES ON THERMAL OXIDATION OF CERTAIN HIGH TEMPERATURE HETEROCYCLIC POLYMERS
 AUTHOR(S): R. T. Conley; S. Ghosh; J. J. Kane
 CONTRACT NO: F33615-68-C-1277
 CONTRACTOR: Wright State University
 PROJECT MONITOR: G. F. L. Ehlers (AFML/MBP)
 PROJECT NO: 7342
 TASK NO: 734203
 ABSTRACT: An extensive investigation was conducted into chemistry of the thermooxidative degradation of certain heterocyclic all-aromatic polymers generally classified as high temperature polymers. Included in this series are benzimidazole, benzimidazolone, benzimide, and quinoxaline polymeric systems. These results are discussed and interpreted in terms of the general mechanistic aspects of oxidative degradation of benzenoid-heterocyclic system which is shown to involve initial attack by oxygen at the amine portion of the polymer repeat unit.

AFML/MB

REPORT NO: AFML-TR-73-239 AD 770 447
ACCESS NO: 202,048 November 1973
TITLE: HYDRAULIC GRIP SYSTEM FOR
COMPOSITE TUBE SPECIMENS
AUTHOR(S): A. Nagy; U. S. Lindholm
CONTRACT NO: F33615-72-C-1703
CONTRACTOR: Southwest Research Institute
PROJECT MONITOR: J. M. Whitney (AFML/MBM)
PROJECT NO: 7340
TASK NO: 734003
ABSTRACT: A hydraulic grip system has been designed, fabricated and undergone preliminary testing. The grip is specifically designed for the testing of fiber-reinforced composite materials in the thin-walled tubular specimen configuration. This is an important test specimen because it allows for determination of all orthotropic material strength parameters from a single specimen configuration. Preliminary testing of the grip system reported herein shows that the principle design objectives of maximum axial and torsional load transfer capability and of active dimensional compensation in the grip have been achieved. Further testing experience is now required to define and optimize control features.

REPORT NO: AFML-TR-73-248 AD 915 745L
ACCESS NO: 202,150 December 1973
TITLE: EXPLORATORY DEVELOPMENT LEADING TO
IMPROVED MATERIALS FOR SELF-SEALING
AIRCRAFT FUEL SYSTEMS
AUTHOR(S): J. D. Ballentine; F. Geerligns, J. R. Kulesia
CONTRACT NO: F33615-71-C-1526
CONTRACTOR: UNIROYAL, Incorporated
PROJECT MONITOR: T. L. Graham (AFML/MBE)
PROJECT NO: 7340
TASK NO: 734005
ABSTRACT: Self-sealing fuel cell constructions were developed with improved capability for sealing wounds inflicted by .50 caliber and 14.5 mm. armour piercing incendiary projectiles but at an increase in weight penalty. All attempts to develop high temperature stable, reliable self-sealing elastomeric fuel cell materials composite were thwarted because of poor adhesion at elevated temperature. Although preliminary screening tests on small specimens pinpointed effective reinforced fluoroelastomer cell components, the large test panel composites prepared developed flaws in adhesion on exposure to high temperature and performed unsatisfactorily when gunfire tested for self-sealing reliability at room temperature.

REPORT NO: AFML-TR-73-261
ACCESS NO: 202, 332 November 1973
TITLE: TIME AND TEMPERATURE DEPENDENCE OF
BORON-EPOXY AND GRAPHITE-EPOXY
LAMINATES
AUTHOR(S): R. A. Heller; G. W. Swift; W. W. Stinchcomb;
A. B. Thakker; J. C. Liu
CONTRACT NO: F33615-72-C-2111
CONTRACTOR: Virginia Polytechnic Institute and State University
PROJECT MONITOR: K. L. Jerina (AFML/MBM)
ABSTRACT: In order to develop techniques for accelerated
characterization of composite materials, tests have been performed on
Boron/Epoxy and Graphite/Epoxy specimens. Results of vibration tests
and constant strain rate tests at various temperatures are reported together
with some preliminary fatigue and damage studies.

REPORT NO: AFML-TR-73-273
ACCESS NO: 202, 334 June 1973
TITLE: DEGRADATION REACTIONS IN POLYMERS
AUTHOR(S): N. Grassie; R. Jenkins; J. Cunningham;
I. G. MacFarlane
CONTRACT NO: F61052-69-C-0026
CONTRACTOR: University of Glasgow
PROJECT MONITOR: I. J. Goldfarb; H. Rosenberg (AFML/MBP)
ABSTRACT: This report is concerned with three distinct
aspects of polymer degradation and stability with the general aim of the
production of materials of improved stability through a more complete
understanding of their degradation mechanism and its relationship to chemi-
cal structure. The photothermal degradation of copolymers of methyl
methacrylate and n-butyl acrylate covering the whole composition range has
been studied at 165°C. The gaseous and liquid products, which consist of
hydrogen, carbon monoxide, methane, methyl methacrylate, n-butyl
acrylate, n-butanol and n-butyraldehyde were analyzed quantitatively using
a gas chromatograph technique and yields related to copolymer composition.
Zip lengths, calculated from molecular weight and volatilization data, de-
crease with increasing acrylate content of the copolymer but are higher than
those observed during thermal degradation.

REPORT NO: AFML-TR-73-291
ACCESS NO: 202, 202 December 1973
TITLE: EXPLORATORY DEVELOPMENT OF HIGH
TEMPERATURE RESINS FOR STRUCTURAL
ADHESIVES AND LAMINATES
AUTHOR(S): R. J. Milligan; C. B. Delano
CONTRACT NO: F33615-73-C-5003
CONTRACTOR: Whittaker Corporation
PROJECT MONITOR: T. J. Aponyi (AFML/MBC)
PROJECT NO: 7340
TASK NO: 734003
ABSTRACT: A second generation polybenzimidazoquinazoline,
PIQ, polymer has been developed that has twice the lifetime of the AF-R-
530 resin in air at 700^oF both in composites and as the free resin. The
resin, coded AF-R-553 (80) is obtained from the reaction of the AF-R-500
amine with the same triazine based traifunctional ester used to prepare the
AF-R-530 resin, the difunctional biphenyl based ester, used to prepare the
AF-R-550 resin, in a molar ratio of 1 to 6. The AF-R-553 system comple-
ments the performance of the AF-R-530 resin. Hence, the AF-R-530 pro-
vides much higher initial strengths in composites than the AF-R-553 but
retains these 700^oF strengths for only about 100 hours.

SYSTEMS SUPPORT DIVISION (AFML/MX)

REPORT NO: AFML-TR-71-276, Vol. II
ACCESS NO: 68,714 April 1972
TITLE: FLIGHTWORTHY GRAPHITE FIBER REINFORCED
COMPOSITE AIRCRAFT PRIMARY STRUCTURAL
ASSEMBLIES

AUTHOR(S): R. D. Hayes
CONTRACT NO: F33615-69-C-1490
CONTRACTOR: Northrop Corporation
PROJECT MONITOR: F. J. Fechek (AFML/MX)
ABSTRACT: Program activities were categorized into 12 tasks:
(1) component selection and preliminary design; (2) materials development;
(3) test and quality control procedures development; (4) design allowables
and criteria; (5) design allowables testing; (6) analysis procedure assessment
and definition; (7) intermediate and final demonstration item design; (8) fabri-
cation procedures development; (9) hardware fabrication; (10) demonstration
item testing; (11) specification development; and (12) cost effectiveness
evaluation.

REPORT NO: AFML-TR-72-249
ACCESS NO: 201,548 January 1973
TITLE: INVESTIGATION OF SOLID CADMIUM EMBRITTLE-
MENT IN A-7 AIRCRAFT FAILED SHAFTS AND
HORN FRACTURE SURFACE

AUTHOR(S): O.H. Cook; R. E. Duval; C. J. Ford; R. W. White
CONTRACT NO: F33615-72-C-1609
CONTRACTOR: LTV Aerospace Corporation
PROJECT MONITOR: F. H. Meyer, Jr. (AFML/MXA)
PROJECT NO: 7381
TASK NO: 738107
ABSTRACT: Solid cadmium embrittlement can cause cracking in
high strength steels if there is intimate contact between cadmium and steel;
the steel is heat treated; and a tensile stress acts parallel to the surfaces.
The A-7 aircraft horizontal tail actuator shaft and horn assembly were
investigated for embrittlement failure. This investigation conclusively proved
that solid cadmium embrittlement was not the cause of failure, and that hydro-
gen embrittlement was the failure mode. This indicates that hydrogen embrit-
tlement cracking will occur in cadmium plated high strength steels where
moisture is present at lower stress levels than solid cadmium embrittlement.

REPORT NO: AFML-TR-73-8
ACCESS NO: 65,834 May 1973
TITLE: SURFACE FLUID AND BOUNDARY LAYER INTER-
ACTION ASPECTS OF TRANSPIRATION-COOLED
NOSETIP CONCEPTS
AUTHOR(S): H. Gold
CONTRACT NO: F33615-69-C-1656
CONTRACTOR: Avco Corporation
PROJECT MONITOR: C. A. Pratt (AFML/MXS)
PROJECT NO: 7381
TASK NO: 738102
ABSTRACT: An experimental program was carried out to investigate the interaction between a surface liquid film and a supersonic turbulent boundary layer. Photographic and heat transfer data were obtained of surface water films on a 33.6 degree wedge and on a 1 inch nose radius, 10 degree sphere-cone model. Aspects of the surface liquid film/boundary layer interaction are the effects of film instabilities on (1) the liquid film; (2) the gaseous boundary layer; and (3) the downstream gas-vapor region. Predictions of mass flux distributions and downstream liquid film cooling lengths are presented for a porous sphere-cone nosetip at zero and non-zero angle-of-attack for typical reentry environments.

REPORT NO: AFML-TR-73-14, Vol. I AD 909 067L
ACCESS NO: 201,352 February 1973
TITLE: PROBABLE AND AVERAGE PROPERTIES OF
ATJ-S(WS) GRAPHITE
AUTHOR(S): H. S. Starrett; C. D. Pears
CONTRACT NO: F33615-71-C-1437
CONTRACTOR: Southern Research Institute
PROJECT MONITOR: C. A. Pratt (AFML/MXS)
PROJECT NO: 7381
TASK NO: 738102
ABSTRACT: This report contains a compendium of the data generated at Southern Research on ATJ-S(WS) graphite. The data are in summary form (averages and standard deviations) and are intended to provide uniform computer inputs for the purposes of predictions (not analyses) in preliminary design and analysis. The data presented are "as measured" and no provisions are made for conservative design. All the data are based on the results from uniaxial tests. Overall properties obtained in this fashion do not provide basis for precise prediction for a single billet from the population. For data on single billets and problems related to uniformity (rather than reproducibility) one should see Volume II.

REPORT NO: AFML-TR-73-14, Vol. II AD 910 641L
ACCESS NO: 201, 352 May 1973
TITLE: MECHANICAL PROPERTIES OF TWO BILLETS OF
ATJ-S(WS) GRAPHITE
AUTHOR(S): H. S. Starrett
CONTRACT NO: F33615-71-C-1437
CONTRACTOR: Southern Research Institute
PROJECT MONITOR: C. A. Pratt (AFML/MXS)
PROJECT NO: 7381
TASK NO: 738102
ABSTRACT: Two billets of ATJ-S(WS) graphite have been characterized with respect to their mechanical properties. Tensile, compressive, and torsional evaluations were performed. The results of the mechanical measurements show that the trends of elastic properties for these two billets were typical. Strain-to-failure (criteria) values for Billet 13KO-20 were atypical. Preliminary NDT inspections and monitors indicated this billet to be atypical. Tensile measurements were used to define property profiles within each individual billet. The results of these measurements showed the property profiles to be quite pronounced and the same trends were shown by both billets. The presence of these profiles prohibits use of the large bank of qualification data on this material for the purpose of establishing design allowables.

REPORT NO: AFML-TR-73-14, Vol. III AD 912 401L
ACCESS NO: 201, 352 June 1973
TITLE: MECHANICAL AND THERMAL PROPERTY DATA
FOR AN YTTRIA STABILIZED ZIRCONIA, A LOW
DENSITY CARBON FOAM AND THERMAL PROPERTIES OF A POLYESTER-SISAL MATERIAL
AUTHOR(S): J. K. Legg; W. T. Engelke
CONTRACT NO: F33615-71-C-1437
CONTRACTOR: Southern Research Institute
PROJECT MONITOR: C. A. Pratt (AFML/MXS)
PROJECT NO: 7381
TASK NO: 738102
ABSTRACT: This document presents results of thermal and mechanical evaluations of an yttria stabilized zirconia, a low density carbon foam, and a polyester-sisal material. In Section I, the thermal conductivity, heat capacity, thermal expansion, and tensile properties of an yttria stabilized zirconia are presented. The results of these evaluations indicate the material was dimensionally stable up to 3400°F; unstable above 3400°F. The cracking of the thermal conductivity specimens and the shoulders of a few tensile specimens indicated a thermal shock sensitivity. In Section II, the thermal conductivity and compressive properties of a low density carbon foam are presented. The total thermal conductivity of this porous material was a function of the solid conduction and the conduction of its gaseous environment. The average solid conduction was about 3.5 Btu in./hr ft²°F.

ABSTRACT (Cont'd): The value in environments of various gases could be approximately calculated by adding the conductivity of the gas to the solid conduction value. In Section III, the thermal conductivity properties from 10°F. to 350°F are presented for a polyester-sisal material in the across lamina direction. The values increased from 3.0 Btu in./hr ft²°F at 10°F to a maximum of 3.6 Btu in./hr ft²°F at 190°F. Above 190°F, the values decreased slightly to 3.3 Btu in./hr ft²°F at 350°F.

REPORT NO: AFML-TR-73-14, Vol. IV AD 913 899L
ACCESS NO: 201,352 September 1973
TITLE: MECHANICAL AND THERMAL PROPERTIES OF MOD 3
AUTHOR(S): J. K. Legg; H. S. Starrett; H. G. Sanders; C. D. Pears
CONTRACT NO: F33615-71-C-1437
CONTRACTOR: Southern Research Institute
PROJECT MONITOR: C. A. Pratt (AFML/MXS)
PROJECT NO: 7381
TASK NO: 738102
ABSTRACT: Three billets of Mod 3 were characterized with respect to the mechanical and thermal properties of the material in order to provide preliminary engineering design data. Material variability and difficulties in obtaining representative test sections resulted in considerable data scatter; however, reasonable probable value curves were generated which can be used for preliminary design. Also, insight was gained on the appropriate test techniques and specimen configurations required to generate representative data on bulk CC composites.

REPORT NO: AFML-TR-73-21 AD 907 910L
ACCESS NO: 201,294 February 1973
TITLE: CARBON/CARBON PERFORMANCE IN A ROCKET NOZZLE
AUTHOR(S): I. C. Swenson; R. M. Hale
CONTRACT NO: F33615-72-C-1773
CONTRACTOR: Lockheed Aircraft Corporation
PROJECT MONITOR: W. Wheeler and F. Vahldiek (AFML/MXS)
PROJECT NO: 14577202817
ABSTRACT: The uses of X-ray diffraction, scanning electron microscopy, and X-ray enhancement were evaluated to determine their utility in distinguishing variations in Carb-I-Tex 700 capable of influencing the behavior of that material in a rocket nozzle application. Data were obtained from Carb-I-Tex pieces taken from billets later machined into nozzle inserts, plates taken from the manufacturing lots of Carb-I-Tex covered by this study, radiographs of Carb-I-Tex inserts, nozzles fired at Lockheed Propulsion Company, and normal specification acceptance testing.

ABSTRACT (Cont'd): Data obtained from the study indicate that earlier work performed in product improvement/process control of the Carb-I-Tex has been successful. All lots and pieces of Carb-I-Tex evaluated were shown by the evaluation techniques to be satisfactory for nozzle usage, fired-nozzle data confirms this evaluation. The test methods evaluated have been shown to have significance in process control and, to a degree, in predicting performance characteristics. A significant process improvement in radiographic techniques for X-ray enhancement has been developed and demonstrated.

REPORT NO:	AFML-TR-73-79	AD 761 817
ACCESS NO:	201, 567	March 1973
TITLE:	THE COLLECTION, GENERATION, AND ANALYSIS OF MIL-HDBK-5 ALLOWABLE DESIGN DATA (1972-1973)	
AUTHOR(S):	P. E. Ruff; R. J. Favor; W. S. Hyler	
CONTRACT NO:	F33615-71-C-1381	
CONTRACTOR:	Battelle Memorial Institute	
PROJECT MONITOR:	D. A. Shinn (AFML/MXA)	
ABSTRACT:	AFML has contracted with Battelle's Columbus Laboratories (BCL) to provide the planning, coordination, and implementation activities necessary to maintain current design allowable data in the Handbook, which is the primary source for design allowable data for metallic materials, fasteners, joints, and other structural elements used in the design of aerospace vehicles. The services provided by BCL for the MIL-HDBK-5 program involve the following: an assessment of the design data requirements of the aerospace industry; liaison with appropriate Government agencies, military services, aerospace contractors, and metallic material suppliers; collection of data; statistical analysis of data to determine design allowable properties; preparation of proposals which contain the revisions to MIL-HDBK-5 for the incorporation of new data; presentation of these proposals at the twice-yearly Government-industry coordination meetings for approval; and revision of MIL-HDBK-5 to incorporate these approved changes.	

REPORT NO: AFML-TR-73-83 AD 766 335
ACCESS NO: 201, 732 April 1973
TITLE: MECHANICAL PROPERTIES, FRACTURE TOUGHNESS, FATIGUE, ENVIRONMENTAL FATIGUE CRACK GROWTH RATES AND CORROSION CHARACTERISTICS OF HIGH-TOUGHNESS ALUMINUM ALLOY FORGINGS, SHEET AND PLATE

AUTHOR(S): C. F. Babilon; R. H. Wygonik; G. E. Nordmark; B. W. Lifka

CONTRACT NO: F33615-71-C-1571

CONTRACTOR: Aluminum Company of America

PROJECT MONITOR: A. W. Gunderson (AFML/MXE)

PROJECT NO: 7381

TASK NO: 738106

ABSTRACT: The mechanical properties, including toughness and fatigue, fatigue crack growth rates and corrosion characteristics have been determined for a total of 56 lots of 7049-T73 and 7175-T736 forgings, 7475-T61 and T761 sheet and 2124-T851 plate. Supplemental data for bare and Alclad 7475 sheet and 2124-T851 plate are also presented. Log-mean fatigue lives were calculated from tests made in ambient air. Axial-stress fatigue tests were also made in a salt fog environment. All of the materials are resistant to stress corrosion exfoliation. All of the materials are resistant to stress corrosion cracking when stressed in the longitudinal and long-transverse grain direction. The resistance to SCC in the short-transverse direction of all the materials is representative of the respective alloys and tempers.

REPORT NO: AFML-TR-73-114 AD 762 305
ACCESS NO: 201, 570 June 1973
TITLE: ENGINEERING DATA ON NEW AEROSPACE STRUCTURAL MATERIALS

AUTHOR(S): O. L. Deel; P. E. Ruff; H. Mindlin

CONTRACT NO: F33615-72-C-1280

CONTRACTOR: Battelle Memorial Institute

PROJECT MONITOR: C. L. Harmsworth (AFML/MXE)

PROJECT NO: 7381

TASK NO: 738106

ABSTRACT NO: The major objectives of this research program were to evaluate newly developed materials of interest to the Air Force for potential structural airframe usage, and to provide "data sheet" type presentations of engineering data for these materials. The effort covered in this report has concentrated on X2048-T851 plate, 7050-T7351 plate, 21-6-9 annealed sheet, Ti-8Mo-8V-2Fe-3Al STA sheet, Ti-6Al-2Zr-2Sn-2Mo-2Cr STA plate, and Ti-6Al-6V-2Sn STA isothermal die forgings. The properties investigated include tension, compression, shear bend, impact, fracture toughness, fatigue, creep and stress-rupture, are stress corrosion at selected temperatures.

REPORT NO: AFML-TR-73-126 AD 769 344
ACCESS NO: S-523 June 1973
TITLE: CONFERENCE ON TRANSPARENT AIRCRAFT
ENCLOSURES
AUTHOR(S): R. E. Wittman
CONTRACTOR: Internal
PROJECT MONITOR: R. E. Wittman (AFML/MXE)
PROJECT NO: 7381
TASK NO: 738106
ABSTRACT: The purpose of this report is to make available the technical papers presented at the recent Tenth Conference on "Transparent Aircraft Enclosures". This conference was held for the exchange of knowledge on new developments and design concepts concerned with vision areas of crew enclosures. Also to make known the state-of-the-art with respect to transparent plastics, interlayer materials, and glass, of the type suitable for these applications.

REPORT NO: AFML-TR-73-128, Vol. I & II
ACCESS NO: 202, 252 May 1973
TITLE: AFFDL 50 MW RENT FACILITY CALIBRATION
AUTHOR(S): C. A. Powars; K. A. Green; W. S. Kennedy;
R. A. Rindal; T. J. Dahm
CONTRACT NO: F33615-70-C-1105
CONTRACTOR: Acurex Corporation
PROJECT MONITOR: G. L. Denman (AFML/MXS)
PROJECT NO: 7381
ABSTRACT: Procedures for calibrating the test stream produced by the AFFDL 50 MW Reentry Nosetip Test (RENT) arc heater facility were developed and demonstrated, and a limited matrix of calibration measurements were carried out. The swept null point calorimetry method was developed to enable measurement of the extremely high heat fluxes characteristic to this facility. This new technique enabled measurement of the jet heat flux profile while saving the instrument for reuse. Fast response pressure probes were also swept across the jet to measure pressure profiles and distributions. Phase I consisted of instrumentation check-out with particular emphasis on verification of the swept null point method and optimization of null point fabrication techniques. Phase II consisted of the actual heat flux distribution, pressure distribution, and enthalpy calibration measurement program, with primary emphasis on the 80 atmosphere impact pressure test condition. Phase III consisted of additional measurements to characterize the time and spatial stability of the jet high energy core.

REPORT NO: AFML-TR-73-151, Vol. I AD 915 099L
ACCESS NO: 79,036 July 1973
TITLE: THERMAL AND MECHANICAL PROPERTY
SCREENING OF GRAPHITE MATERIALS FOR
ADVANCED REENTRY VEHICLES VOLUME I
AUTHOR(S): J. K. Legg; S. G. Bapat; H. S. Starrett;
C. D. Pears
CONTRACT NO: F33615-69-C-1796
CONTRACTOR: Southern Research Institute
PROJECT MONITOR: C. A. Pratt (AFML/MXS)
ABSTRACT: This report presents the results of a thermal and
mechanical property screening program conducted on graphite materials
developed for advanced reentry vehicles under the Air Force Development
Program (ADP). The results are reported for each material in the form of
an individual data book. Volume I contains a description of the apparatuses
and procedures used in the evaluation of thermal and mechanical properties
and DATA Books A through E. ATJ-S(W) was selected as the base line for
comparison with other graphites of this program.

REPORT NO: AFML-TR-73-186 AD 913 976L
ACCESS NO: 78,842 October 1973
TITLE: HIGHER STRAIN GRAPHITES
AUTHOR(S): H. S. Starrett; H. G. Sanders; A. D. Cull;
C. D. Pears
CONTRACT NO: F33615-72-C-1043
CONTRACTOR: Southern Research Institute
PROJECT MONITOR: C. A. Pratt (AFML/MXS)
PROJECT NO: 7381
TASK NO: 738102
ABSTRACT: The objective of the project was to characterize
certain advanced graphitic materials to provide information for material
improvement and for design parameter studies. The three phases of the
program were as follows: Phase I-A preliminary evaluation of the seven
materials; Phase II-Elimination of some materials and testing of three;
Phase III-A rapid comprehensive design allowable program was instituted
for the purpose of rejecting bad billets from the single material left. A
broad array of test techniques NDT for detecting both bulk and isolated
defects was conducted as were mechanical tests.

REPORT NO: AFML-TR-73-197
ACCESS NO: 69,334 August 1973
TITLE: DEVELOPMENT OF ENGINEERING DATA ON
THICK-SECTION ELECTRON BEAM WELDED
TITANIUM
AUTHOR(S): J. G. Bjeletich
CONTRACT NO: F33615-71-C-1338
CONTRACTOR: Lockheed Palo Alto Research Laboratory
PROJECT MONITOR: C. L. Harmsworth (AFML/MXE)
PROJECT NO: 7831
TASK NO: 738106
ABSTRACT: Some high performance aerospace structures are fabricated of titanium plate. Presently, Ti-6Al-4V, in the mill-annealed condition, is the titanium alloy most commonly used for this application. A potential choice is the recently developed alloy, Beta III, in the solution treated and aged condition. This report provides a vital portion of the basic engineering data necessary for the design of reliable and efficient airframe structures involving electron-beam weldments in the two alloys. Tensile, fracture toughness, and subcritical crack growth properties of both base metal and weldments have been obtained for 1- and 2-in. Ti-6Al-4V and 1-in. Beta III plate.

REPORT NO: AFML-TR-73-231 AD 914 473L
ACCESS NO: 202,019 November 1973
TITLE: DESIGN DATA FOR AS-3DX QUARTZ/SILICA
COMPOSITE MATERIAL
AUTHOR(S): T. M. Place
CONTRACT NO: F33615-72-C-1516
CONTRACTOR: Philco-Ford Corporation
PROJECT MONITOR: J.R. Rhodehamel (AFML/MXE)
PROJECT NO: 7381
ABSTRACT: This report contains data resulting from a comprehensive measurement program defining and characterizing the mechanical, thermophysical, and dielectric properties of AS-3DX, a 3D reinforced silica composite, from -100° to 1800°F. Mechanical measurements include tensile, compression, torsion, and impact data in the two principal axes of the composite. Specific properties include ultimate strengths, elastic moduli, strain to failure, Poissons ratio, and proportional limit stresses. Thermophysical measurements of thermal expansion, specific heat, and thermal conductivity are also presented. Dielectric constant and loss tangent were measured from 1 to 24 GHz.

REPORT NO: AFML-TR-73-269 AD 773 559
ACCESS NO: 202,296 November 1973
TITLE: ENGINEERING DESIGN DATA FOR ALUMINUM
ALLOY 7050-T73651 PLATE
AUTHOR(S): R. E. Jones; K. A. Fudge
CONTRACT NO: F33615-72-C-1282
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: D. C. Watson (AFML/MXE)
PROJECT NO: 7381
TASK NO: 738106
ABSTRACT: Mechanical properties of aluminum alloy 7050-T73651 one-inch thick plate were determined and then compared to other high strength aluminum alloys. The fracture, fatigue crack growth, and stress corrosion properties and the flaw sensitivity index for the 7050-T73651 alloy were equal to or better than similar properties for other 7000 series aluminum alloys at similar strength levels. Conventional notched and smooth fatigue data indicated that the 7050-T73651 alloy had fatigue properties somewhat below those of 7049-T73, but equal to most other aluminum alloys. Environmental fatigue crack growth tests indicated that the crack growth rate was significantly accelerated by the presence of a 3.5 per cent sodium chloride solution environment. Changes in the specimen width were found to have an effect on the conditional fracture toughness values.

REPORT NO: AFML-TR-73-286 AD 915 103L
ACCESS NO: 79,035
TITLE: EROSION MECHANISMS AND IMPROVEMENT OF GRAPHITIC MATERIALS
AUTHOR(S): C. E. Swain; R. B. Dirling, J. D. Baldwin
CONTRACT NO: F33615-72-C-1540
CONTRACTOR: McDonnell-Douglas Corporation
PROJECT MONITOR: C. A. Pratt and G. L. Denman (AFML/MXS)
PROJECT NO: 7381
TASK NO: 738102
ABSTRACT: This document presents a summary of surface roughness characterization measurements taken on C-CAP materials and the results of a parametric study of rough wall heat transfer on graphitic materials. Both studies were aimed at an improved understanding of the ablation performance of bulk graphites and carbon-carbon materials by defining those parameters which most affect ablation performance. Detailed measurements of surface roughness height, width, and spacing were taken on seven posttest specimens from the carbon-carbon assessment program.

TECHNICAL SERVICES DIVISION (AFML/TU)

REPORT NO: AFML-TR-73-137 AD 769 341
 ACCESS NO: 201,934 August 1973
 TITLE: COMPOSITIONAL ANALYSIS OF LEAD LANTHANUM
 ZIRCONIUM TITANATE

AUTHOR(S): J. H. Muntz
 CONTRACTOR: Internal
 PROJECT MONITOR: J. H. Muntz (AFML/TUA)
 PROJECT NO: 7360
 TASK NO: 736005

ABSTRACT: Lead lanthanum zirconium titanate has shown promise as an electronic ceramic. The composition of the materials is important to provide the proper physical and electronic properties. Wet chemical analysis does not always give adequate results and an alternate method of analysis was developed. With this method the lead is determined by an atomic absorption technique and La, Ti, and Zr determined by optical emission technique. Accuracy evaluated by the sum of the oxides of the metals determined is usually $100\% \pm 1\%$. Precision for the lead determination is indicated by a relative standard deviation of less than $\pm .5\%$. For the other three elements determined by optical emission the relative standard deviation is $\pm 2 - 3\%$. This is adequate to characterize the composition of the synthesized material.

REPORT NO: AFML-TR-73-181 AD 767 226
 ACCESS NO: 201,792 July 1973
 TITLE: DEVELOPMENT OF A SELF-CONTAINED PORT-
 ABLE UNIT FOR NONDESTRUCTIVE COMPOSI-
 TIONAL ANALYSIS OF AIRCRAFT AND SPACE
 SYSTEMS ALLOYS

AUTHOR(S): J. M. Brinkerhoff
 CONTRACT NO: F33615-71-C-1897
 CONTRACTOR: Parametrics, Inc.
 PROJECT MONITOR: C. D. Houston (AFML/TUA)
 PROJECT NO: 7360
 TASK NO: 736005

ABSTRACT: Two portable radioisotope excited x-ray fluorescence systems have been designed and delivered, one a high resolution type utilizing a cryogenically cooled solid state detector and the other a gas filled proportional counter operated in conjunction with balanced x-ray filters. The measurement probes were designed for sample areas that may be of small size or that may occur in recessed locations. Measurement techniques were formulated and studied that utilize pure elemental standards in conjunction with just a single alloy reference for a given unknown. Computational

AFML/TU

ABSTRACT (Cont'd): programs were written to implement these techniques. A set of twenty-seven analyzed reference alloys was also provided. This report summarizes the design aspects of the two systems and the course of evaluation of the measurement techniques.

PLANS OFFICE (AFML/XR)

REPORT NO: AFML-TR-73-35 AD 768 312
ACCESS NO: 202,151 April 1973
TITLE: AIR FORCE MATERIALS LABORATORY FY 74
TECHNICAL OBJECTIVE DOCUMENT
AUTHOR(S): B. Chasman
CONTRACTOR: Internal
PROJECT MONITOR: B. Chasman (AFML/XR)
ABSTRACT: This Technical Objective Document was prepared by the AFML and describes the Materials Technology Planning Objectives for meeting future AF operational needs. The six Technology Planning Objectives encompass the full spectrum of materials capabilities required for future aircraft, missile, space and electronic systems, Thermal Protection Materials; Aerospace Structural Materials; Aerospace Propulsion Materials; Fluid, Lubricant and Elastomeric Materials; Protective Coatings and Materials; Electromagnetic Materials. Presented for each TPO is the general objective, specific goals and technical approaches, and a Laboratory TPO focal point who can facilitate face-to-face discussions with Laboratory engineers and scientists. This report supersedes TOD 71-26.

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AUTOMATED	AUTOMATED SHIELD AND WIRE ASSEMBLY MANUFACTURING METHODS	069726/055

AVERAGE	PROBABLE AND AVERAGE PROPERTIES OF ATJ-S(WS) GRAPHITE	201352/121
A1-TETRAPHENYL-	CATIONIC POLYMERIZATION OF VINYL-SUBSTITUTED MONOMERS WITH A,A,A1, A1-TETRAPHENYL-P-XYLYL BISCARBONIUM HEXACHLOROANTIMONATE	201679/094
A-7	INVESTIGATION OF SOLID CADMIUM EMBRITTLEMENT IN A-7 AIRCRAFT FAILED SHAFTS AND HORN FRACTURE SURFACE	201548/120
A,A,A1	CATIONIC POLYMERIZATION OF VINYL-SUBSTITUTED MONOMERS WITH A,A,A1, A1-TETRAPHENYL-P-XYLYL BISCARBONIUM HEXACHLOROANTIMONATE	201679/094
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BAG	IMPROVED ADVANCED COMPOSITE BAG MOLDING PROCESSES	201696/066
BALL	PLANETARY BALL SWAGING OF WELDED TITANIUM ALLOY TUBING	067738/069
BARIUM	BARIUM SODIUM NIOBATE AS A NONLINEAR OPTICAL MATERIAL	201291/039
BBB	EXPLORATORY DEVELOPMENT OF THE INVESTIGATION OF METHODS TO PROCESS BBB, BBL, AND RELATED POLYMERS	202078/115
BBL	EXPLORATORY DEVELOPMENT OF THE INVESTIGATION OF METHODS TO PROCESS BBB, BBL, AND RELATED POLYMERS	202078/115
BEAM	COMPOSITE BOX BEAM OPTIMIZATION. EXPERIMENTAL DATA SUPPORTING TECHNIQUE DEVELOPMENT AND PRELIMINARY DESIGN	069663/006
BEAM	DEVELOPMENT OF ENGINEERING DATA ON THICK-SECTION ELECTRON BEAM WELDED TITANIUM	069334/128
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BEARING	INTERACTION BETWEEN PERFLUOROALKYL POLYETHER LINEAR AND CYCLIC DERIVATIVE FLUIDS AND HIGH TEMPERATURE BEARING STEELS IN OXIDATION-CORROSION ENVIRON	202204/110
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BIBENZIMIDAZOLE	PROTON MAGNETIC SPECTRA OF POLY (M-PHENYLENE BIBENZIMIDAZOLE)-LITHIUM CHLORIDE SOLUTIONS IN DIMETHYLACETAMIDE	201932/106
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BIQUINOLINE	SYNTHESIS OF AROMATIC AND HETEROCYCLIC PERI ACIDS PART II. BIQUINOLINE, PHTHALAZINE AND NAPHTHOXYPHENYL SULFONE PERI ACIDS	202047/086
BISCARBONIUM	CATIONIC POLYMERIZATION OF VINYL-SUBSTITUTED MONOMERS WITH A,A,A1, A1-TETRAPHENYL-P-XYLYL BISCARBONIUM HEXACHLOROANTIMONATE	201679/094
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DERIVATIVE	INTERACTION BETWEEN PERFLUOROALKYL POLYETHER LINEAR AND CYCLIC DERIVATIVE FLUIDS AND HIGH TEMPERATURE BEARING STEELS IN OXIDATION-CORROSION ENVIRON	202204/110
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MATRIX	THE MECHANICAL BEHAVIOR OF METAL MATRIX COMPOSITES	202070/029
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METAL-RARE	TECHNOLOGY DEVELOPMENT FOR TRANSITION METAL-RARE EARTH HIGH-PERFORMANCE MAGNETIC MATERIALS	202159/040
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STEEL	EVALUATION OF AFC 77 MARTENSITIC STAINLESS STEEL FOR AIRFRAME STRUCTURAL APPLICATIONS	200674/029
STEEL	MANUFACTURING TECHNOLOGY FOR MATERIALS, DESIGNS, AND FABRICATION OF EXTRUSION DIES FOR HOT EXTRUDING OF STEEL AND TI STRUCTURAL SECTIONS	068001/057
STEELS	EXPLORATORY DEVELOPMENT ON HYDROGEN EMBRITTLEMENT OF HIGH-STRENGTH STEELS DURING MACHINING	202049/035
STEELS	INTERACTION BETWEEN PERFLUOROALKYL POLYETHER LINEAR AND CYCLIC DERIVATIVE FLUIDS AND HIGH TEMPERATURE BEARING STEELS IN OXIDATION-CORROSION ENVIRON	202204/110
STEPPING	AN INEXPENSIVE UNIVERSAL STEPPING MOTOR CONTROLLER	201776/109
STORAGE	MANUFACTURING METHODS FOR FABRICATION OF MESHLESS STORAGE DISPLAY	067445/051
STRAIN	PLASTIC SHEAR PROPERTIES OF METALS AND ALLOYS AT HIGH STRAIN RATES	202069/028
STRAIN	PLASTIC DEFORMATION OF METALS AT HIGH STRAIN RATES. PART II STEADY-STATE CRACK PROPAGATION IN A PLATE SUBJECTED TO COMBINED BENDING AND TENSION	202007/022

STRAIN	PLASTIC DEFORMATION OF METALS AT HIGH STRAIN RATES. PART I THE EFFECTS OF TEMPERAURE ON THE STATIC AND DYNAMIC STRESS-STRAIN CHARACTERISTICS IN TOR	202006/021
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STRENGTH	HARDNESS, STRENGTH, AND ELONGATION CORRELATIONS FOR SOME TITANIUM-BASE ALLOYS	202022/021
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STRENGTH	HIGH STRENGTH, HIGH MODULUS ALB2 FLAKE REINFORCED COMPOSITES	202203/098
STRENGTH	THE EFFECTS OF ENVIRONMENTAL EXPOSURE ON STRENGTH PROPERTIES OF AF-A-3639 ADHESIVE BONDED JOINTS	201846/103
STRENGTH	PRESTRESSING OF BORON AND GRAPHITE EPOXY PREPREG FOR COMPOSITE STRENGTH IMPROVEMENT	201617/104
STRENGTH	EXPLORATORY DEVELOPMENT ON FORMATION OF HIGH STRENGTH, HIGH MODULUS BORON NITRIDE CONTINUOUS FILAMENT YARNS	201684/081
STRENGTHENED	GROWTH OF TITANIUM AND CHROMIUM STRENGTHENED SAPPHIRE FIBERS	201385/010
STRENGTHENING	SOLID SOLUTION SOFTENING (RHENIUM DUCTILIZING EFFECT) AND BUBBLE STRENGTHENING IN TUNGSTEN-RHENIUM ALLOYS	201935/034
STRENGTHENING	SOLID SOLUTION STRENGTHENING AND DISPERSION HARDENING IN DILUTE TITANIUM ALLOYS	201618/025
STRENGTH-HIGH	MANUFACTURING METHODS FOR HIGH STRENGTH-HIGH MODULUS GLASS FIBER	069009/049
STRESS	STRESS CORROSION CRACKING OF TITANIUM AND TITANIUM BASE ALLOYS IN AQUEOUS AND GASEOUS MEDIA	201830/036
STRESS	CRACK TIP STRESS INTENSITY FACTORS IN FINITE ANISOTROPIC PLATES	202230/114

STRESS	ANALYTICAL INVESTIGATION OF STRESS CONCENTRATIONS DUE TO HOLES IN FIBER REINFORCED PLASTIC LAMINATED PLATES, THREE-D MODELS	201569/102
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STRUCTURAL	APPLICATION OF RELIABILITY ANALYSIS TO AIRCRAFT STRUCTURES SUBJECT TO FATIGUE CRACK GROWTH AND PERIODIC STRUCTURAL INSPECTION	201595/018
STRUCTURAL	DESIGN GUIDE FOR USE OF STRUCTURAL SHAPES IN AIRCRAFT APPLICATIONS	201791/070
STRUCTURAL	MANUFACTURING TECHNOLOGY FOR MATERIALS, DESIGNS, AND FARRIGATION OF EXTRUSION DIES FOR HOT EXTRUDING OF STEEL AND TI STRUCTURAL SECTIONS	068001/057
STRUCTURAL	EXPLORATORY DEVELOPMENT OF HIGH TEMPERATURE RESINS FOR STRUCTURAL ADHESIVES AND LAMINATES	202202/119
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